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PROCEEDINGS OF THE SOCIETY OF ARTS

FORTY-THIRD YEAR, 1904-1905

BOSTON, January 26, 1905.

THE 604th regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, on Thursday evening, January 26, at eight o'clock, Mr. J. P. Munroe in the chair. The records of the previous meeting were read and approved. Professor William H. Lawrence, of the Institute, and Mr. Jesse J. Eames, of Boston, were elected members of the Society. Mr. William Atkinson, of Boston, then addressed the Society on "The Orientation of Buildings; or the Planning of Buildings and Streets with Regard to Sunlight." The lecture was illustrated with a number of slides. The thanks of the Society were extended to the speaker, and the meeting adjourned.

BOSTON, February 9, 1905.

The 605th regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, on Thursday evening, February 9, 1905, at eight o'clock, two hundred and ten being present. Dr. Theobald Smith presided. The records of the previous meeting were read and approved.

A paper was then presented by Dr. Charles Wardell Stiles, of the Public Health and Marine Hospital Service, on "The Hookworm Disease: a New and Important Parasitic Disease of Man." The speaker described the methods by which the organism was discovered, and showed by maps its geographical distribution in America, and pointed out the relationships between the hookworm of the Southern States and similar parasites which are found in other parts of the world. A discussion of the symptoms and the treatment of the disease followed. The announcement was made that the disease is entirely curable by comparatively simple treatment. The lecture was illustrated with a number of interesting lantern slides.

A brief discussion followed, and the meeting adjourned.

BOSTON, February 23, 1905.

The 606th regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, on Thursday evening, February 23, 1905, at eight o'clock. About two hundred persons were present. Professor W. T. Sedgwick presided. The records of the previous meeting were read and approved.

The Society was then addressed by Erastus G. Smith, Ph.D., Professor of Chemistry in Beloit College, Beloit, Wisconsin, who spoke on "The Purification of Public Water Supplies in the Middle West." The speaker described the relation of the natural waters to the different geological formations in the West, and explained in detail the nature and great variety of the problems that the sanitarian encounters in dealing with different waters. The water supplies of a number of Western cities were discussed in detail, with the special problems encountered in each case, especially Denver; Ashland, Wisconsin; Davenport, Iowa; Rock Island and Moline, Illinois; and St. Louis, Missouri.

The lecture was illustrated by a large number of slides.

The subject of water supply was further discussed by Professor Sedgwick, Mr. Robert S. Weston, and others.

The thanks of the Society were extended to the speaker, and the meeting was adjourned.

BOSTON, March 16, 1905.

The 607th regular meeting of the SOCIETY OF ARTS was held in Room 23, Walker Building, on Thursday evening, March 16, 1905, at eight o'clock. Professor Harry E. Clifford presided. About two hundred members were present.

The paper of the evening was presented by Mr. John Stone Stone, who spoke on the subject of "Wireless Telegraphy." The lecture was illustrated by a large number of diagrams, showing the results of Mr. Stone's researches on this subject. A vote of thanks was extended the speaker, and the Society adjourned.

BOSTON, March 29, 1905.

The 608th regular meeting of the SOCIETY OF ARTS was held at the Institute of Technology, Room 22, Walker Building, on Wednesday evening, March 29, 1905, at eight o'clock. Professor C. F. Allen presided. Sixty-five persons were in attendance.

Mr. Charles B. Breed, of the Civil Engineering Society of the Institute, addressed the Society on "The Abolition of Grade Crossings in Chicago by Track Elevation."

Mr. Breed described the scope of the work, and the method employed in raising the tracks without stopping freight and passenger traffic, and called special attention to the engineering details. He also gave some interesting statistics as to the number of grade crossings abolished, the number of miles of elevated track in Chicago, and the cost of changing the grades; and spoke of the future of the work. The lecture was illustrated by lantern slides showing the work at different stages. After some questions and discussion a vote of thanks was extended to the speaker, and the Society adjourned.

BOSTON, April 13, 1905.

The 609th regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, on Thursday evening, April 13, 1905, at eight o'clock. Mr. George W. Blodgett, chairman of the Executive Committee, presided. About sixty-five persons were present. The minutes of the previous meeting were read and approved.

The chairman then presented Professor George H. Barton, Curator of the Teachers' School of Science, who gave a most interesting account of "The Physiography and Geography of Hawaii." Professor Barton spoke of the physiographic changes which have taken place during the past twenty-five years, or between his first and second visit to the islands, and mentioned also the economic development which has taken place.

The lecture was illustrated by a large number of interesting lantern slides. The thanks of the Society were extended to the speaker, and the Society adjourned.

BOSTON, April 27, 1905.

The 610th regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, on Thursday evening, April 27, 1905, at eight o'clock. Professor Harry E. Clifford presided. About forty persons were present. The minutes of the previous meeting were read and approved. The appointment of a nominating committee was then called for, this committee to be appointed by the chair. Messrs. H. E. Clifford, J. F. Norris, W. L. Underwood, R. P. Bigelow, and the Secretary were appointed. The chairman then presented Mr. Philip W. Davis, of Boston, who spoke on "Storage Batteries," giving an account of their development, of the different types of batteries now in use, and of their applicability either on a large or small scale. He described in detail some of the most important plants which are now receiving power from this source. The lecture was illustrated by a large number of interesting lantern slides and diagrams. The thanks of the Society were extended to the speaker, and the meeting adjourned.

SAMUEL C. PRESCOTT, *Secretary*.

CONTRIBUTION FROM THE SANITARY RESEARCH LABORATORY AND SEWAGE EXPERIMENT STATION OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

II

THE INTERPRETATION OF AN ANALYSIS OF THE EFFLUENT FROM A SEWAGE FILTER

BY EARLE B. PHELPS

(Received April 3, 1905)

IN a previous paper the writer (1905) has described certain characteristics of a sewage, in terms of which the analytical figures may be interpreted, in order that sewages may be described and classified with reference to purification. The subject of sewage filter effluents, requiring, as it does, a distinctly different manner of treatment, was not considered at that time. The proper interpretation of the analyses of such effluents, however, is equally important in experimental work, and is the essential point in the work of the practical sewage filter. In the present paper it is the intention to discuss this phase of the sewage purification problem. Septic sewage was considered in the previous paper as a sewage to be purified. It must also be considered here, but as a partially purified effluent.

The subject of the quality of the effluents derived from a sewage filter has been considered from two totally different points of view, which have led frequently to conflicting opinions as to the results obtained. One view is based upon the actual work of the filter expressed in percentage efficiency, and necessarily takes into account the nature of the raw sewage. The other is based upon the quality of the effluent as shown by the analysis.

The former is, as a rule, the point of view of the investigator who is comparing the work of several types of filters upon the same sewage, and who finds in the percentage efficiencies of the several filters a convenient basis for such comparisons. The latter is the broader view of the sanitarian and of the public health official, whose duty it is to

inquire, not what is the percentage removal of organic matter, but what will be the probable effect upon the health and comfort of the communities below of the discharge of this effluent into a stream. Both viewpoints must be taken, each supplementing the other.

The expression, "percentage removal," sometimes called the efficiency of the filter, is of very little value in the comparison of systems which are not receiving the same sewage, for it is much easier to get a high efficiency, calculated in this way, on a strong sewage than on one which is weaker. The figure in any case is of real value only when it is based upon determinations which are themselves total and not partial determinations. For example, it is obvious that the total organic nitrogen or total organic carbon of the raw sewage and of the effluent may be directly compared; but the comparison of such partial values as those of the albuminoid ammonia or of the oxygen consumed will give only misleading results. Whatever value such determinations may have in the comparison of like substances is entirely lost when the substances are unlike. The removal of bacteria may properly be expressed in the form of efficiency, but in the case of very good effluents this form of expressing results fails in another respect, in that a very short range of numerical efficiencies covers a wide range of actual conditions. For example, it might not readily be noted that in a given filter a change from 99.9 per cent. to 99.8 per cent. in the bacterial efficiency would mean a doubling of the bacteria in the effluent, while smaller but significant changes in the effluent would not appear in the efficiency number. On the whole it would seem that a better interpretation of the analysis of an effluent can be made than this customary comparison with the raw sewage. A direct comparison of effluents derived from the same sewage will serve the purposes of the investigator fully as well as a comparison of the efficiencies, while the quality of the effluent is the final and practical criterion upon which the work of the filter must be judged.

Historical. Standards of Purity

In an act of the English Parliament of 1861, entitled "Local Government Act Amendment Act" (Great Britain, 1861), a provision prohibits the construction of new sewer outfalls which shall discharge any "sewage or filthy water into any natural water course or stream until such sewage or filthy or refuse water be freed from all excrementitious or other foul or noxious matter such as would affect or dete-

riorate the purity and quality of the water in such stream or water course." This act is of interest in that it is the first law, in England at least, requiring treatment of sewage. At that time no standards were available, and it would be of interest to learn just how it was determined when all such "excrementitious and foul matter" had been removed.

As early as 1872 (Great Britain, 1872), the first Rivers' Pollution Commission of England recommended the following standards of purity for effluents. A nonpolluting liquid shall not contain in 100,000 parts over three parts of mineral matter or over one part of organic matter in suspension; nor in solution shall it contain over two parts of organic carbon or 0.3 part organic nitrogen. This standard would have prevented the discharge of any but the most perfectly purified effluents. The recommendations were never embodied in the law, and never since that time have the established standards been so exacting. The following standards, all expressed in parts per 100,000, have almost legal force in the various districts of England (Rideal, 1902) — Thames Conservancy: organic carbon 3.0, organic nitrogen 1.1; Derbyshire County Council: albuminoid ammonia 0.1, oxygen absorbed 1.0; Ribble Board: albuminoid ammonia 0.1, oxygen absorbed 2.0; Mersey and Irwell: albuminoid ammonia .14, oxygen absorbed 1.4.

It will be seen at once that mere dilution of the effluent will bring it within the limits of any such standards, which are based upon actual amounts of organic matter present. It is even claimed by the sanitary inspectors that certain manufacturers use this method as their sole means of bringing their waste liquors down to the required standard.

Since the introduction of the more recent biological processes our ideas of purity of effluents have been gradually changing. In many of these processes, but most notably in the case of the continuous, or trickling, filter, a large amount of organic matter is passed through the filter, which upon examination generally proves to be of a peaty or humus nature and incapable of further putrefactive change. Aside from the possibility of such material creating a nuisance by forming deposits behind milldams or in the lower reaches of the stream, it appears to be entirely harmless and nonoffensive. Chemical analysis fails to distinguish between the ordinary putrescible matter of sewage and this non-putrescible material which results from the treatment of the sewage in the manner indicated. This has led to the introduction of putrescibility, or incubation, tests which are now so commonly used.

These depend in general upon the storage of the effluent in a bottle at summer temperature and out of contact with the air for a period of several days. Certain tests are then made upon this incubated sample to determine if it has undergone putrefaction. The determination of the oxygen consumed before and after incubation is the one most frequently employed. Many chemists determine the loss of dissolved oxygen and of nitrates either in the original effluent or after mixing it with certain quantities of aërated water or nitrate solution.

Attention has also been called to the value of the nitrates in an effluent. Gayon and Dupetite (1886) have shown that denitrification is a direct combustion of organic carbon at the expense of the oxygen of the nitrates. Experiments of Adney and of Letts tend to confirm this view. It is also brought out by these investigators that the free dissolved oxygen likewise takes part in the reactions, carbon dioxide being evolved in amount corresponding to the free oxygen used up. Thus instead of adhering to the older view that all organic matter is harmful and must be kept below a certain maximum standard value, the more recent practice is to balance the available oxygen against the organic matter, and, if the former be found in excess, to consider the effluent satisfactory. The question remaining to be settled, and on which there are many views, is just how much of the oxygen is available and how much of the organic matter requires oxidation.

These and other considerations have led to the construction by Rideal (1902) of a formula for the discharge of effluents into a stream, which he proposes as a practical standard of purity for effluents. This formula is:—

$$C = \frac{XO}{(M-N)S},$$

in which

X = Flow of the stream in hectoliters per minute.
O = Grams of free oxygen in 1 hectoliter
S = Hectoliters of effluent discharged per minute.
M = Grams of oxygen required to consume the organic matter in 1 hectoliter of effluent as determined by the permanganate test, boiling for four hours and deducting for the nitrites.
N = Grams of available oxygen as free oxygen, nitrate, and nitrite ($2O_2$ for N_2O_5, O_2 for N_2O_3).
C = Ratio between the amount of oxygen in the stream and the amount of this required to oxidize the organic matter.

This formula serves to distinguish three possible cases. If C be negative, the effluent not only will not putrefy by itself, but by virtue of its excess of available oxygen will tend to improve the condition of the stream, if the latter be already polluted. If C be greater than unity, the effluent will draw upon the oxidizing power of the stream, diminishing the power of the latter to deal successfully with further pollution; but in this case the stream will not itself become foul from this effluent. If C be positive, but less than unity, the stream will be overburdened by the addition of the effluent, and will become foul.

In England, where the subject of streams pollution has received careful study, the opinions of the experts on this question of standards vary greatly. The late Sir Edward Frankland (1902), in his testimony before the Royal Sewage Commission, restated the proposition advanced by him in 1874, that "there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation." Frankland also expressed distrust of the incubation test, believing it to be unreliable. On the other hand, the position taken by Rideal, that all free oxygen, as well as the oxygen of the nitrates and nitrites, is available to complete the oxidation of the remaining organic matter, was supported by much of the testimony. The same views are embodied in a test proposed by Adney (1902), who would incubate a sample of the effluent after diluting with river water in the proportion in which the two are mixed in the river. Then if no putrefaction occurs the effluent is satisfactory.

This test represents the extreme view of that school of sanitarians who hold that, if a partially purified effluent can be supplied with sufficient available oxygen for the complete oxidation of the remaining organic matter, it may with safety be discharged into the stream, and the purification will be completely carried out within the stream. In justice to this view, it should be stated that what is here attempted is apparently not the protection of the streams from pollution by disease germs so much as the prevention of an apparent nuisance in, or fouling of, the stream. The evident intention is to keep the stream in such a condition that it may be rendered fit for domestic use by further purification of the water.

With our present knowledge, at least, this would seem to be the wiser provision. We know little, unfortunately, of the viability of disease organisms in sewage and of the effect of purification treatment upon them. While the ideal condition, and the one toward

which sanitarians should ever be working, is the perfect purification of sewage from all pathogenic bacteria before discharge, it may nevertheless be better economy, with our present information, so to purify our sewage as to prevent it from seriously fouling the streams and to thoroughly purify all waters taken from them for domestic use. With the idea, therefore, of interpreting our analyses of effluents in accordance with this view, let us examine our analytical procedure in connection with the purification processes to see what significance each of the substances determined has upon the interpretation of the analysis of an effluent. At the same time the fact must not be overlooked that practically perfect purification from the bacterial point of view is entirely feasible, and in many cases desirable. The question of the interpretation of slow-sand-filter effluents will, therefore, naturally be included in the present discussion.

Nitrogen

According as the conditions of the purification process are aërobic or anaërobic, the nitrogen of the organic molecule may follow one or the other of two very different courses. In the slow sand filter and also in the percolating, or trickling, filter, in both of which types there is a plentiful supply of oxygen, the course of all the nitrogen seems to be from organic molecule to ammonia, and thence to nitrites and nitrates. In a very good sand filter as much as 99 per cent. of the organic nitrogen may be thus accounted for. On the other hand, Farrell and the writer (1905) have recently shown that in the contact system of purification, while as much as 25 per cent. of the total nitrogen may follow this course, a large part of the remainder is converted, under the anaërobic conditions of the reduction phase, into the amine form, and that these amines in turn react with the nitrites previously formed. This reaction causes a liberation of a large percentage of the total nitrogen in the form of the free gas. As much as 50 per cent. of the total may thus disappear. In the septic tank also nitrogen is liberated, but in this case the liberation is brought about by the direct action of the microörganisms upon the organic molecule. Kinnicutt and Eddy (1901) have published the results of what is probably the most careful study ever made of the amount and composition of the gas given off in the septic tank. As a result of their work upon the Worcester sewage, extending over a period of a little over two years, they found for the first fifteen months the average amount of

gas evolved was 2.3 gallons per 100 gallons of sewage, and that of this gas 32 per cent. was nitrogen. A simple calculation shows this amount to represent 9.8 parts per million of sewage. The total nitrogen value for the raw sewage, as given by Eddy (1901), is 42.5 parts per million, so that 23 per cent. of the total is evolved in the tank as nitrogen gas. During the following year the average results similarly calculated are 8.5 parts per million evolved, or 17 per cent. of the total nitrogen of the sewage. The latter figure itself is not given for that year, and is here calculated approximately by the formula proposed by Fuller (1903), which is,

$$\text{Total organic nitrogen} = \frac{12 \times (\text{albuminoid nitrogen})^2}{\text{ammoniacal nitrogen}}.$$

Similar calculation made upon some results obtained by Clark (1900) on the Lawrence sewage shows an evolution of nine parts per million of nitrogen in a sewage which contains approximately forty parts per million of nitrogen as calculated by the above formula. The nitrogen evolved in this case is therefore about 22 per cent. of the total.

In Manchester, England, Fowler (1901) has made some analyses and measurements of the gas in a septic tank. His results, calculated into parts of nitrogen per million, give 12.5 parts. Averages of the raw sewage are not given, but, judging from the septic tank effluent, the sewage is of about the same strength as that of Lawrence.

Knowledge of the actual amount of nitrogen escaping from the septic tank or from a contact filter is obviously of great importance, and the value of total nitrogen determination as an index of the work of these processes is evident.

The Free Ammonia. — The free ammonia being a transition stage in the purification process is not of much significance in those rapid processes of treatment where a large amount of ammonia is produced in a short time. While it is strictly an inorganic substance, and in every way harmless, yet the fact must not be overlooked that it is not a stable compound when discharged into a stream. All the free ammonia must be oxidized at the expense of the free oxygen of the stream, and its effect in thus reducing the power of the stream to further purify organic matter must be allowed for. This fact is not considered in Rideal's formula previously given. In very pure effluents, such as those from sand filters, the free ammonia, being extremely low, is a valuable index of the work of the filter. In such cases it may

be said that it runs very nearly parallel with the organic nitrogen as well as with the bacteria.

Nitrites. — The nitrites are likewise transition substances, and are extremely unstable. In filters of the oxidizing type, nitrites are a valuable indication of the condition of the filter. When such a filter is running at its best, the nitrites will, as a rule, be low. A marked increase in the nitrite value is then an indication that something has gone wrong with the filter. Considered with reference to the stream, they are of value in that they possess available oxygen, although as a rule the amount of nitrites present is too small to be of any value in this respect. Their great importance in the reactions of the contact filter has already been alluded to.

Nitrates. — Nitrates are the final product of the oxidation of the organic nitrogen. Their appearance in sand and trickling filters is, therefore, of great significance, in that they indicate the actual amount of work done by the filter. Their relation to the quality of the effluent is also important. They carry the largest amount of the available oxygen of the effluent, and it is now believed by most authorities that they may be entirely consumed in the process of secondary oxidation, which takes place in the stream after the discharge of the effluent. Any arbitrary standard for purity for effluents from such filters should therefore contain, in addition to a maximum allowable amount of organic matter, a minimum amount of nitrates. In such a case mere dilution of an effluent could never bring it to the desired condition, while with high nitrates an effluent will not generally become foul or offensive by secondary putrefaction.

Authorities are not yet in agreement as to the significance of nitrates in the contact filter effluent. This point has been discussed in detail in the paper on the contact filter previously referred to (Phelps and Farrell, 1905), and will not be taken up here. The writer's opinion is that since nitrates are used up in the work of the filter, their appearance in the effluent merely indicates that an excess has been formed, and that if necessary the filter may be worked harder. Perfectly stable effluents may be obtained practically free from nitrates.

Carbon

The organic carbon is determined only partially by the oxygen-consumed test. While this test has a certain value in the comparison

of effluents from similar filters, and especially as a quick method for controlling a filter, it has no scientific basis whatever, and the relation of its results to the total carbon is, so far as the writer is aware, unknown. In a few experiments made by Mr. Roger L. Rice under the writer's direction it was found that the percentage of the total carbon of various organic substances given by this test varied all the way from a few per cent. in the case of cane sugar to 100 per cent. in the case of such bodies as ammonium oxalate. The futility, therefore, of attempting to calculate the efficiency of a process upon the basis of the test is apparent. It has been claimed that with a four hours' boiling this process determines the total carbon, and Rideal has worked out his formula for purity of effluents on this assumption. The subject of the determination of the total carbon by a method which shall be fairly accurate and at the same time sufficiently rapid and easy for routine sewage work is one which should receive the attention of sewage chemists. The question whether or not the oxygen consumed as now determined, or as it may be determined by some modification of the present process, bears any significant relation to the total can then be considered, and it is very possible that a relation may be obtained which shall show the ease with which the organic carbon can be oxidized. This latter point is, of course, an important one in the consideration of the stability of the effluent. The oxygen-consumed determination is of undoubted value in the putrescibility tests, which will be considered later.

Oxygen

Free dissolved oxygen in the effluent represents a reserve oxidizing power by which the effluent can further purify itself. Its presence also indicates that there has been a sufficient supply of this necessary element during the process of purification. The effluents of oxidizing filters, sand and trickling filters, should always contain free oxygen. If all the oxygen is used up, then the process is not being properly worked. In the contact-filter effluent the free oxygen has another significance. The supply of oxygen being necessarily somewhat limited in this type of filter, it will become most completely exhausted in that filter which is doing the most work. We find that this is actually the case at the Sewage Experiment Station treating Boston sewage. Our best contact-filter effluents are, as a rule, free from dissolved oxygen, while others, although less well purified, contain oxygen. This effluent,

which is free from dissolved oxygen, might be looked upon with suspicion but that it contains high nitrates, and has thus an available reserve of oxygen in another form. There may be some doubt as to which of these two effluents is really the better. They would doubtless both give similar values for C in Rideal's formula. Incubation tests are strongly in favor of the one containing nitrates.

Putrescibility Tests

By putrescibility we denote that property of the organic matter in a sewage or effluent which causes it, under certain conditions, to undergo putrefactive change. Thus gelatin is a putrescible substance, while peat is a good example of a non-putrescible, or stable, substance. For the purposes of sewage work, the organic matter dealt with may be roughly grouped into these two classes, for it is now pretty generally conceded that, in addition to the readily putrescible organic matter which characterizes sewages, there is also found in effluents organic matter of the other class, that is, stable organic matter. Bodies belonging to this latter group may already exist to some extent in the raw sewage, and they are the characteristic end-products of the rapid oxidation of the sewage in a trickling filter. They are not produced appreciably in the anaërobic decompositions of the septic tank, and would, therefore, appear to be the result of the direct oxidation of the organic molecule rather than of its hydrolitic cleavage. This view may be illustrated by the two following hypothetical reactions: —

$$\text{Oxidation, } 2R{-}N{=}R' + 3O_2 = R{-}O{-}R + 2R'{=}O + N_2O_3.$$

$$\text{Hydrolysis, } R{-}N{=}R' + H_2O = R{-}OH + R'{=}NH.$$

In other words, hydrolytic cleavage produces amines and complex, perhaps unsaturated, hydroxyl bodies, while oxidation produces ultimately oxides of nitrogen and organic molecules which do not readily take up more oxygen.

Water analysts feel strongly the need of distinguishing between these two classes of bodies in potable waters represented by animal pollution on the one hand and by vegetable extractive matter on the other. Many attempts have been made to devise an analytical process for this purpose. Woodman (1898) has proposed a method which is worthy of wider adoption. He would determine the oxygen consumed by the regular method from permanganate and again from chromic acid.

The ratio between these two values is a characteristic one for each of the two classes of material. The water analyst, however, has other determinations upon which he can rely to aid in his interpretation. The chlorine, nitrites, and nitrates each have their own significance, and help to explain the origin of the organic matter.

In sewage analysis nothing in the ordinary procedure serves to give any clew to this question of the character of the organic matter. Therefore about 1895 Scudder (1902) devised as a simple method of studying this point the test which has since come to be known as the incubator test. In its earliest form this test consisted in completely filling a bottle with the effluent and keeping it stoppered at a warm summer temperature for a few days. If it was then free from odor and from all signs of decomposition, it was considered nonputrescible. Later Scudder placed this test upon a more scientific basis by determining the oxygen consumed from permanganate in the cold in three minutes, the dissolved oxygen and the nitrates both before and after incubation. A putrescible effluent as defined by him will have lost part of or all its dissolved oxygen and nitrates, and will absorb an increased amount of oxygen from permanganate.

The writer's experience with the incubation test upon many kinds of effluents leads him to believe that the observed changes in the amount of available oxygen and in the oxygen-consuming power of the effluent during incubation serve to indicate three different conditions of the effluents, rather than two only, and that the interpretation of the test from this point of view makes it the most valuable one in our analytical procedure. The following classification of the results of the test will make this view plain: —

1. There is no loss of available oxygen during the incubation.
2. There is loss of available oxygen.

a. The loss is only partial. The oxygen-consumed value is unchanged or diminished. The effluent remains clear without the production of disagreeable odor.

b. The loss is total. The oxygen-consumed value is increased. Putrefaction has occurred with the production of disagreeable odors, and usually of a dark sediment.

In case 1 the organic matter is stable, or nonputrescible, in the true sense of the word. Such an effluent would pass the incubation test in its strictest form as recommended by Scudder. Case 2 *a* represents an effluent whose organic matter is not completely stable. The

putrescibility of this organic matter is not determined by the test, since anaërobic conditions have not been established. This material might, under such conditions, have become putrescent, but the supply of available oxygen in the effluent is more than sufficient to render it stable and nonputrescent. Although the available oxygen is diminished and the effluent would not, therefore, pass the test as used by Scudder, it is nevertheless apparent that it contains within itself the power to complete its own purification, and thus could not under any conditions become foul. Case *2 b* is an example of an effluent which cannot complete its own purification, and would draw upon the purifying power of the stream. Its effect upon the stream, therefore, would depend upon other considerations, namely, relative volumes of the stream and of the effluent, character of the stream as regards previous pollution and available oxygen, etc. For the further study of such an effluent Adney's proposed test will be of service. This test consists in mixing the effluent with the water of the stream in the proportion of the relative volumes of their flows, and then incubating. Whether or not the stream will be able to complete the oxidation of the effluent will be shown by this test. But one must not overlook the fact that one is working here on a very narrow margin of safety, and careful consideration must be given to the possible seasonal variations in the quality and flow of the stream. In general, effluents of this character ought not to be discharged. They constitute pollution even when no immediate nuisance is produced. Their effect upon the river is cumulative, and in the case of a stream receiving such effluents from a number of communities the first discharge might be of untreated sewage, while the communities lower down would be obliged to produce a very pure effluent in order to prevent fouling of the stream.

In carrying out the determinations connected with the incubation test certain special methods of procedure are necessary. For example, it is found that the determination of the oxygen consumed by the shorter English method — three minutes in the cold — rather than by the hot method emphasizes greatly the changes occurring during the incubation. The writer has also found it quite necessary to determine the amount of permanganate which is instantly used up in the cold. This instantaneous value determines the hydrogen sulphide, ferrous salts, and other products of reduction accompanying anaërobic fermentation, and includes also the nitrites, if any are present. After correcting this value for the nitrites, any marked increase after incubation

is indicative of putrefaction having taken place. The determination of the free oxygen and the nitrates after incubation will be unnecessary unless it be desired to distinguish between Class 1 and Class 2*a* as described. In the writer's opinion no such separation is necessary, since effluents of either class are either stable or will rapidly become so. In fact, it is only effluents of the highest degree of purity which will fall into Class 1. Such effluents will, as a rule, be produced only when necessary for the protection of water supplies, and in such cases a much more delicate test, such as the bacteriological examination, would naturally be relied upon.

It will be observed that the conditions established by these incubation tests correspond with the three conditions defined by Rideal's formula (page 126), the difference lying in the way in which the oxygen required for complete oxidation is determined. The use of such a formula as a substitute for the incubation test would be highly desirable. It must first be shown, however, that the oxygen consumed from permanganate is practically the same as that used up during incubation. Obviously by boiling for four hours with permanganate a much greater amount is used up than would be required by the effluent to render it stable. The Lawrence method of boiling for two minutes would probably give deficient values. This is a point worthy of further study, since it determines at once the most important character of the effluent — its stability.

Filtered and Unfiltered Samples. Turbidity, Color

In effluents showing an appreciable turbidity, the determination of the total nitrogen upon the sample after filtration through paper will give additional information. Since it may be assumed that a large part of the suspended solids will eventually find its way to the bed of the stream, this information will be of practical value to the analyst. The writer has found the determination of the putrescibility upon such a filtered sample to be also of service. In some cases a mere settling out of the grosser matter will serve to change the character of the effluent from one slightly putrescible to one thoroughly satisfactory. As a measure of the absolute amount of suspended matter in the effluent, a quantitative reading of the turbidity as described in an earlier paper will be of service.

The color of clear effluents of high purity often serves as a useful

indication of slight changes in the work of the filter. Where a high degree of purification is not attempted the color of the effluent is of no value whatever.

The odor of the effluent is often of significance to the analyst, although the difficulty of correctly describing such an odor in intelligible terms lessens the value of this test as a matter of record. The writer has used a set of terms for odors in sewages and effluents which are sufficiently self-explanatory to any other analyst engaged in the same work to render them of some service. They are as follows: *Sewage*, the odor of fresh sewage as it flows in a city sewer, especially in winter. *Septic*, the characteristic odor of septic sewage, which often persists after passage through the filter. *Musty*, as used in water analysis; generally characteristic of contact filters. *Earthy*, the odor of fresh, clean earth, characteristic of trickling filter effluents. *Vegetable*, as used in water analysis, characteristic of well-purified sand-filter effluents. The numerical expression of the intensity of the odor, as recommended by Whipple (1901), is used in connection with these terms with fairly satisfactory results. The odor after incubation is obviously of great value in the interpretation of that test.

Bacteria

When we consider that the removal of pathogenic organisms from the sewage is one of the prime reasons for its purification, it is unfortunate that the advance of knowledge in this particular subject has been very much slower than on the purely chemical and engineering sides. The actual removal of pathogenic organism from water by sand filtration has been experimentally demonstrated, and a study of the vital statistics of certain localities before and after purification of a polluted water supply leaves no room to doubt that a fairly complete removal of such organisms by sand filtration is possible. It might thus very well appear that in the case of sewage a careful purification through sand filters, which reduces the total bacteria to a figure permissible in a filtered water supply, will also have effectively removed the pathogenic forms.

The organisms supposed to be the cause of nitrification in the filters have been extensively investigated. Qualitative studies other than these are not very often made. What little information exists at present on this important subject is for the most part too meagre

to allow of any general conclusions as to the significance of any given organism or groups of organisms in an effluent. One important exception to this statement, however, must be made in the case of the organisms *Bacillus coli* and *B. enteritidis*. The occurrence of these two organisms in the effluents of sewage filters has been made the subject of an extensive study by Houston and McGowan (1902), who show that in a series covering a wide range from raw sewage to completely purified effluents the unpurified organic matter of the effluent is roughly proportional to the numbers of colon bacilli, to the numbers of *B. enteritidis*, and to the numbers of organisms producing gas in sugar gelatin. As a practical test they have selected the latter group of organisms, whose approximate numbers can readily be estimated by the dilution method. The practical standard of purity proposed is that the effluent shall not contain over ten of these gas-producing organisms per cubic centimeter. In the extensive comparison made this standard in every case served to distinguish between the satisfactory and unsatisfactory effluents.

Another important line of work has been indicated by Clark and Gage (1905). These investigators have found that a large percentage of the total number of organisms passing through a sewage filter consists of a relatively small number of species. These species are carefully counted on the gelatin plate, and a number of each kind fished for further study. In this study the ability of each organism to liquefy gelatin, ammonify peptone, oxidize ammonia to nitrites and nitrates, and to reduce nitrates to nitrites, ammonia, and free nitrogen is determined quantitatively. The quantitative power of any organism to produce ammonia from peptone times the number of organisms of that kind present in a cubic centimeter of the effluent is the ammonifying power of that organism in the effluent. The sum of the ammonifying powers of all the organisms present constitutes the ammonifying coefficient of the effluent. Similar coefficients are determined for each of the other functions mentioned. It is too early to venture an opinion upon this work. Since, however, we are dealing with life processes, it would seem that the proper method of determining the properties of an effluent would be a study of the life within the effluent and the chemical changes which the living organisms are capable of producing, or what the authors aptly term the "biochemistry" of the effluent.

Mere quantitative counts of the organisms in the effluent are of no significance except in those effluents in which a high degree of purity

is expected. In such cases the number of organisms present serves as a valuable index of the amount of organic matter in the water.

Other Proposed Tests

Many other tests of minor importance have been proposed for the rapid determination of the character of the effluent. Such tests for the most part lack the merit of being based upon any scientific principle, and are, as a rule, only used for the guidance of the workmen in the control of the filter plant.

At Leeds, England (Harding, 1902), the effluents are passed through small basins in which fish are kept. The fact that fish are thus able to live is taken as evidence that the effluent is satisfactory. Obviously the ability of fish to live in an effluent signifies merely that there is an abundant supply of oxygen and an absence of any great amount of turbidity, facts which could be equally well shown by very simple tests.

In these same basins certain microscopic animals and plants are often found, and upon the character of such growths Walker (1902) has based an interesting biological test for the quality of the effluent. For example, he found that the best effluents, such as those from double contact systems high in nitrates, support a copious growth of the *Chlorophyceæ*, notably *Stigeoclonium* and *Microspira*, while *Oscillaria* and other *Cyanophyceæ* are generally present in small amounts or altogether absent. In slightly inferior effluents these blue-greens predominate, together with *infusoria* and *rotifers*. Still poorer effluents were found to be characterized by the presence of *Beggiatoa* and the infusoria, *Carchesium* and *Vorticella*.

The Derbyshire County Council recommend a "shake test." In this test the effluent is vigorously shaken in a bottle for one minute. In a satisfactory effluent the froth should disappear within three seconds. The significance of this test is not apparent.

Barwise (1904) suggests that the process of purification is accompanied by the conversion of ammonium carbonate into nitrous and nitric acids, a change from alkaline to acid reaction. He therefore recommends the determination of the alkalinity in the raw sewage and in the effluent as a measure of the purification. In sewages containing much cellulose, however, he found the test to be unreliable on account of the production of acids from the cellulose.

Summary and Conclusion

Summarizing briefly the most important points in the analysis of a sewage-filter effluent, it may be said that the determination of the nitrogen in all its forms is of first importance, not alone in indicating the extent of the purification, but as an index of the stability of the effluent; that the determination of the total organic carbon, or its roughly relative estimation by the oxygen-consumed test, ranks next in significance, representing material that still requires oxidation; that the dissolved oxygen is of great significance both as to the condition of the filter and the stability of the effluent; and that a study of the changes occurring during incubation serves to reënforce the analytical data, and is in reality the ultimate criterion upon which the interpretation of such data depends. The value of bacteriological data as indicative of the quality of the effluent is still an unknown quantity, although the writer is inclined to believe that the determination of specific coefficients, as described by Clark and Gage, may eventually become the standard against which we may check our simpler laboratory methods. Such extensive studies are obviously not available in the routine work of the analyst for sewage works, but are of the greatest importance in enabling us to understand the processes with which we are dealing and correctly to interpret our analytical data.

In the following specimen analysis of an effluent are included the important determinations which have been described in the preceding pages.

SPECIMEN ANALYSIS

(Parts per million)

	Total.	Dissolved.	Suspended.	After incubation. Five days at 37°.
NITROGEN:				
Total	50.5	44.5	6.0	. .
Organic	16.0	10.0	6.0	. .
As NH_3	11.0	11.0	. .	. .
As N_2O_5	1.5	1.5	. .	1.0
As N_2O_3	22.0	22.0	. .	15.0
CARBON:				
Total	100.0	70.0	30.0	. .
By $KMnO_4$:				
Cold. Instantaneous	0.1	. .	.	0.1
Three minutes	0.6	. .	. .	0.4
Hot. Thirty minutes	12.4	8.0	4.4	. .
OXYGEN:				
Dissolved	7.2	. .	. .	5.0
TURBIDITY:				
Total	125.0	. .	. .	. .
On standing	25.0	. .	. .	. .
Sediment (diff.)	100.0	. .	. .	. .
COLOR	. .	. .	. .	. .
ODOR	3 earthy		. .	1 musty

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AN OFTEN NEGLECTED FACTOR IN SEWAGE ANALYSIS

By ELLEN H. RICHARDS

In most discussions on the quantitative estimates of the substances to be determined, it seems to be taken for granted that a given sample of sewage may be tested as taken, or at any convenient time, six, twelve, or forty-eight hours after.

A slag from a blast furnace may or may not be stable in its composition; but sewage, full of life and therefore in a state of active change, rendered more active by the increase of temperature in the laboratory over the ground sewer, cannot be treated so carelessly.

Each hour, or perhaps each half hour, changes the relative composition, and, as has been fully determined in other cases, *time* must be considered where *life* is concerned in the changes.

Analysts have been berated because they have not developed a satisfactory system of testing this most complex and changing fluid. The question may fairly be raised, Is not the first step to decide upon a uniform time and temperature to which the sample shall be subjected before testing?

The objection will at once occur to the engineer, "But we wish to know at once while the plant is in operation," just as the blast furnace manager wishes his report before the next charge is added.

True,. but the quick method can be decided upon only after the more complete results are at hand, so that the reliability of the rapid tests may be determined.

The usual object of sewage treatment is to get rid of that vaguely described material, "organic matter." The ammoniacal compounds already formed offer no serious difficulty.

But the substances to be disposed of belong to two classes, (1) easily changing and (2) more or less permanent, and it is just here that analytical methods are weak. Total organic matter may not give the desired data because in one case one-third of it may be in a condition to yield to purification, in another two-thirds, and yet the results of analysis may be the same. A separation of the two classes is much to be desired, or a determination by means of time and incubation at a definite tem-

perature of the amount of increase in certain constituents, as ammonia. Confirmation of the desirability of such study may be found in the results of H. C. Sherman's[1] investigations on milk fresh and stale.

In the practice work by the class of 1905, Sanitary Engineering Course, some indications of the direction in which increased knowledge may come were obtained. They are given as hints for further work.

Two samples received on successive weeks from the Sewage Experiment Station within an hour from the sewers, still cold, were each divided into two portions, and the first portions were started digesting for total nitrogen, were distilled for free and albuminoid ammonia, were treated with aluminum hydrate, and the filtrates subjected to the above tests within four hours; the second portions were treated in the same way on subsequent days, with the following results: —

TABLE I

Parts per million

	Sample No. 1.		Sample No. 2.	
	First day.	Second day.	First day.	Fourth day.
Free ammonia	8.10	13.60	16.8	25.6
Albuminoid ammonia	4.48	. .	6.8	. .
Total by Kjeldahl	20.80	24.32	39.2	. .
Same less free ammonia (subtracted)	11.90	10.72	22.4	14.6
Total after distilling free	. .	10.24	. .	. .
Factor for albuminoid ammonia	2.65	2.28	3.3	2.1

TABLE II — Sample No. 1 Filtered through Double Paper the First Hour after Receiving, Still Cold

	First day.	Third day.	Sixth day.
Free ammonia	8.00	15.20	16.40
Albuminoid ammonia	2.20	2.24	0.96
Total by Kjeldahl	20.16	. .	. .
Same less free ammonia (subtracted)	12.16	. .	. .

[1] Jour. Am. Chem. Soc., 1905, XXVII, p. 124.

TABLE III — SAMPLE NO. 1 TREATED WITH ALUMINUM HYDRATE AND FILTERED WITHIN THE FIRST HOUR

	First day.	Third day.	Sixth day.
Free ammonia	8.0	8.48	10.0
Albuminoid ammonia	2.6	. .	. .
Total by Kjeldahl	16.0	. .	. .
Total less free (subtracted)	8.0	. .	. .
Factor	3.0	. .	. .

TABLE IV — SAMPLE NO. 2 TREATED WITH ALUMINUM HYDRATE FIRST DAY

Free ammonia	13.50
Albuminoid ammonia	2.64
Total by Kjeldahl	29.30
Total less free	15.80
Factor	6.00
Total from original	29.30
Total from precipitate	15.60
	44.90
Total less final free	25.60
Leaving total	19.30

Experienced analysts may draw their own conclusions, but there seems to be a possibility of some separation of the easily decomposable substances and their separate treatment, which may throw some light on the intricate processes which must be more clearly understood before really scientific management can be predicated.

TABLE V — SAMPLE NO. 1. INCUBATED AT 36°

	On the third day.	On the sixth day.
Free ammonia	18.80	16
Albuminoid ammonia	3.08	. .

TABLE VI — A SAMPLE FROM THE SEPTIC TANK

	First day.	Third day.	Sixth day.
Free ammonia	16.48	16	13.4

It would seem that an incubation of twenty-four or thirty-six hours before testing is likely to give more concordant results and to lead to a better balance between applied sewage and effluent. Further tests are needed to prove whether it is common to have so great a discrepancy as shown between the total nitrogen the first hour, 20.80, and the second day, 24.32 (Table I); also if it is a general rule that treatment with aluminum hydrate will remove the easily putrescible substances as indicated by the filtrate of No. 1 remaining nearly unchanged for three days and more (Table III), while the untreated paper filtered (Table II) increased in free ammonia from 8.0 to 15.20 on the third day.

CONTRIBUTIONS FROM THE LABORATORY OF SANITARY CHEMISTRY

X

THE DETECTION OF CANE SUGAR IN MAPLE PRODUCTS

BY A. G. WOODMAN

"PURE Vermont maple sugar" appears every year in our markets long before sugar weather is established or the sap even begins to flow in the maple groves of northern Vermont. There has long been little doubt in the mind of the consumer that the article he buys is not pure maple sugar, but contains in most cases a considerable proportion of refined cane sugar. Owing, however, to the identity in chemical composition of the two sugars, the adulteration has been considered very difficult, if not impossible, to prove. Within the last year, however, the problem has been attacked on somewhat different lines and, to judge from the published reports of state and municipal laboratories, with a considerable degree of success as regards the detection of adulterated goods.

In collaboration with the Bureau of Chemistry of the Department of Agriculture, the writer has had opportunity to test the value of several of the methods proposed for the examination of maple syrups and sugars, both on samples of known purity and on adulterated samples. The results obtained on these are published here, not because they offer anything new, but for the purpose of adding to the analytical data which it will be necessary to gather before standards of permanent value can be fixed.

Three methods were used, the first being the centrifugal method devised by Julius Hortvet, of the Minnesota State Dairy and Food Department, and described by him in a valuable paper in the *Journal of the American Chemical Society*,[1] the same procedure being also detailed in a circular distributed to members of the Association of

[1] Jour. Am. Chem. Soc., 1904, **26**, p. 1523.

Official Agricultural Chemists for criticism before adoption as a provisional method. This method, it will be remembered, consists in measuring the volume of the precipitate formed by the addition of basic lead acetate and "alumina cream" to a solution of 5 c.c. of syrup or 5 grams of sugar, and collected by centrifugal force. The centrifugal machine available happened to be of the same radius as that described by Hortvet, and the speed as measured was 1,600 revolutions per minute. The samples were allowed to stand forty-five minutes, after adding the reagents, before they were whirled.

A second method employed was one attributed to Hill and Mosher, described in a personal communication from Dr. W. D. Bigelow, of the Bureau of Chemistry, and not published elsewhere to the writer's knowledge. This may be described briefly as follows:—

To 50 c.c. of the syrup, diluted with about 200 c.c. of distilled water, add drop by drop to slight excess a saturated solution of neutral lead acetate, warm gently to coagulate the precipitate, let stand until the precipitate settles, and filter, washing until free from soluble lead salts. Transfer the filter and contents to a beaker, add distilled water, and saturate with hydrogen sulphide. Filter, wash, boil out excess of hydrogen sulphide from the filtrate, cool, and titrate with $\frac{N}{10}$ alkali.

The third method consisted mainly in an examination of the ash, chiefly in regard to the determination of the soluble and insoluble ash and their respective alkalinities, following for the most part the suggestions of C. H. Jones, chemist to the Vermont Agricultural Experiment Station, and of Hortvet in the paper previously mentioned.

About 5 grams of syrup or sugar was ignited in a platinum dish over a low flame until it was charred and then heated in a muffle until the ash was white. The addition of a bit of vaseline was found to be an advantage. After weighing the ash it was treated with boiling water, filtered through an ashless filter, and washed. The filtrate was titrated with $\frac{N}{10}$ acid. The filter and residue were ignited in the original dish and, after weighing, warmed with 15 c.c. $\frac{N}{10}$ hydrochloric acid, cooled, and titrated with $\frac{N}{10}$ alkali.

The samples were all from the Bureau of Chemistry, with the exception of the sugar marked "X," which was obtained directly from the maker in Vermont. Samples Nos. 3067, 3076, 3156, and 3159

of the syrups, and 3072, 3092, 3200 of the sugars were obtained from the makers through known sources, and are supposedly pure. The other samples were purchased on the Washington market. Sample "X" was much softer and contained more "molasses" than the others, evidently having been made by the genuine old-fashioned kettle method.

TABLE I — RESULTS OF HORTVET METHOD

SYRUPS.				SUGARS.			
Sample.	Specific gravity.	Reading in cubic centimeters.	Corrected reading, cubic centimeters.	Sample.	Specific gravity.	Reading in cubic centimeters.	Corrected reading, cubic centimeters.
3142	1.33	2.17	1.17	3072	. .	3.07	2.47
3151	1.30	2.18	1.21	3092	. .	4.54	3.94
3156	1.33	2.75	1.62	3138	. .	1.90	1.30
3159	1.32	2.36	1.33	3143	.	1.48	0.88
3067	1.34	2.30	1.27	3145	. .	1.48	0.88
3076	1.34	2.05	1.08	3200	. .	4.87	4.27
. .	. .	. .	. .	"X"	. . .	2.88	2.28

Blank determination = 0.60 c.c.

According to Hortvet, the results on pure maple syrup vary from 0.94 to 1.82 c.c., and on pure sugars from 1.18 to 4.41 c.c.

According to Hill and Mosher, genuine maple syrup gives a colorless, or nearly colorless, filtrate after precipitating the lead with hydrogen sulphide. All syrups known not to be maple gave a brown or black filtrate. All samples known to be genuine required 30 to 35 c.c. $\frac{N}{10}$ alkali per 100 c.c. syrup, equivalent to 0.20 to 0.25 gram malic acid per 100 c.c. syrup. All samples known not to be maple required less than 10 c.c. $\frac{N}{10}$ alkali per 100 c.c. syrup. If genuine maple syrup be diluted with a pure granulated sugar syrup, the only change in results noted is the lower acid figure.

TABLE II — RESULTS OF HILL AND MOSHER METHOD

Sample.	Color after H_2S.	C.c. $\frac{N}{10}$ alkali per 100 c.c.	Grams malic acid per 100 c.c.
		SYRUPS.	
3142	Black	5.62	.038
3151	Black	2.74	.018
3156	White	62.18	.417
3159	White	26.28	.176
3067	Very light brown	36.46	.244
3076	Very light brown	34.24	.229
		SUGARS.	
3072	Black	26.69	.179
3092	Black	15.65	.105
3138	Brown	6.92	.046
3143	Very light brown	1.98	.013
3145	Brown	2.64	.018
3200	Black	17.63	.118
"X"	Black	20.92	.140

The data obtained by Jones on several samples of pure and of adulterated goods are given in Table IV.[1] The lowest limit of ash in pure maple syrup is placed by him at 0.5 per cent., on the basis of 11 pounds of syrup to the gallon. Pure maple products as manufactured in a crude way by the farmers rarely go below 0.6 per cent. in total ash; pure goods manufactured on a larger scale by improved appliances are sometimes lower on account of the more complete removal of sediment by settling and filtration.

[1] For other results obtained by Jones, see also Leach: Food Inspection and Analysis. 1904, p. 770.

TABLE III — Results of Examination of Ash

Sample.	Grams taken.	Ash, per cent.	Soluble ash, per cent.	Insoluble ash, per cent.	Total alkalinity of ash (c.c. $\frac{N}{10}$ acid on 5 grams).	Alkalinity of soluble ash (c.c. $\frac{N}{10}$ acid on 5 grams).	Alkalinity of insoluble ash (c.c. $\frac{N}{10}$ acid on 5 grams).	Alkalinity of 1 gram total ash (c.c. $\frac{N}{10}$ acid).	Alkalinity of 1 gram soluble ash (c.c. $\frac{N}{10}$ acid).	Alkalinity of 1 gram insoluble ash (c.c. $\frac{N}{10}$ acid).	Ratio soluble to insoluble alkalinity, 1 : —	Ratio alkalinity 1 gram soluble to that of 1 gram insoluble ash, 1 : —	Sample.
Syrups													
3142	6.50	0.25	0.17	0.08	1.65	0.98	0.67	132	115	167	0.68	1.45	3142
3151	6.15	0.17	0.12	0.05	1.03	0.58	0.45	120	97	180	0.83	1.85	3151
3156	6.34	0.70	0.46	0.24	5.70	2.76	2.94	163	120	245	1.06	2.04	3156
3159	5.95	0.57	0.36	0.21	4.36	1.85	2.51	153	103	239	1.36	2.32	3159
3067	6.23	0.64	0.32	0.32	4.95	2.05	2.90	155	128	242	1.41	1.89	3067
3076	6.10	0.58	0.39	0.19	4.34	2.18	2.16	150	112	227	0.99	2.02	3076
Sugars													
3072	5	1.07	0.70	0.37	9.46	3.94	5.52	177	112	298	1.40	2.66	3072
3092	5	1.01	0.53	0.48	8.78	3.10	5.68	174	117	237	1.83	2.02	3092
3138	5	0.20	0.11	0.09	1.89	0.74	1.15	189	134	255	1.55	1.90	3138
3143	5	0.08	0.07	0.01	0.86	0.60	0.26	215	171	520	0.43	3.04	3143
3145	5	0.15	0.09	0.06	1.66	0.78	0.88	221	173	293	1.13	1.69	3145
3200	5	0.84	0.36	0.48	8.08	2.46	5.62	192	137	234	2.28	1.71	3200
"X"	5	1.18	0.51	0.67	9.79	2.78	7.01	166	109	209	2.52	1.92	"X"

TABLE IV — Ash Data Obtained by C. H. Jones

Description of sample.	Grams taken.	Ash, per cent.	Soluble ash, per cent.	Insoluble ash, per cent.	Total alkalinity of ash (c.c. $\frac{N}{10}$ acid).	Alkalinity of soluble ash (c.c. $\frac{N}{10}$ acid).	Alkalinity of insoluble ash (c.c. $\frac{N}{10}$ acid).	Alkalinity of 1 gram total ash (c.c. $\frac{N}{10}$ acid).	Alkalinity of 1 gram soluble ash (c.c. $\frac{N}{10}$ acid).	Alkalinity of 1 gram insoluble ash (c.c. $\frac{N}{10}$ acid).	Ratio soluble to insoluble alkalinity, 1 : —	Ratio alkalinity 1 gram: soluble to that of 1 gram insoluble ash, 1 : —
Pure												
Maple syrup, 1904	5.34	0.65	0.46	0.19	5.75	2.75	3.00	164	110	300	1.09	2.73
Maple sugar, 1904	5.22	0.73	0.50	0.23	5.75	2.75	3.00	151	106	250	1.09	2.36
Maple sugar, 1902	5.25	0.90	0.60	0.30	7.50	3.50	4.00	158	110	256	1.14	2.33
Very dark, last run sugar	5.59	1.32	0.57	0.75	13.25	3.00	10.25	179	94	244	3.41	2.60
Maple syrup, 1904	5.35	0.62	0.38	0.24	5.00	2.25	2.75	156	118	211	1 22	1.80
Contain Cane Sugar												
Sugar	5.00	0.36	0.19	0.17	2.50	0.50	2.00	139	53	235	4.00	4.43
Sugar	5.00	0.21	0.13	0.08	2.40	1.00	1.40	229	154	350	1.40	2.27
Sugar, May 21, 1903	10.00	0.19	0.14	0.05	3.75	1.00	2.75	197	80	500	2.75	6.40
Sugar, good flavor, known to be adulterated[1]	5.07	0.31	0.19	0.12	3.00	1.50	1.50	188	150	250	1.00	1.66

[1] 66⅔ per cent. cane, 33⅓ per cent. maple sugar.

Considering first the syrups examined, the Hortvet test would show samples 3076, 3142, and 3151 to be open to suspicion. In the other two methods, however, the color of the hydrogen sulphide filtrate and the alkali required for the malic acid, as well as the data on amount and alkalinity of the ash, indicate that only two of these, 3142 and 3151, are mixed with cane sugar.

In the case of the sugars the Hortvet precipitate and the ash data are quite concordant and show the presence of cane sugar in samples 3138, 3143, and 3145. Although recommended only for syrups, the Hill and Mosher test has been used also in the examination of the sugar samples, without, however, obtaining quite so characteristic results. The amount of standard alkali required for the malic acid bears out the indications of the other two methods, but from the color of the hydrogen sulphide filtrate no definite conclusions could be drawn.

The centrifugal test is rapid and convenient, and as such is most desirable for use as a routine or "sorting out" method to be applied to all samples, to be followed by other confirmatory tests in cases where its indications are at all open to doubt. In the writer's hands this test did not give quite so decisive results as the other two, but its ease of execution renders it of great value. The Hill and Mosher test is rather tedious and disagreeable, but gives characteristic results. With the syrups especially the color of the hydrogen sulphide filtrate was very striking and served excellently to differentiate the impure samples. With the sugar samples it was not found so effective. On the whole, the method giving the most satisfactory and decisive data seemed to be the examination of the ash, especially the proportion of soluble and insoluble ash and their respective "alkalinities."

In conclusion, acknowledgment is gladly made of indebtedness to Mr. G. W. Rolfe for many helpful suggestions.

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THE RAILWAY TELEPHONE SERVICE; COST OF LINE CONSTRUCTION[1]

By FRANK F. FOWLE, S.B.

THE ownership and operation of private telephone lines by railway companies is a proposition which differs essentially from the public exchange and toll business. There are three distinct differences which place the railway telephone service in a separate class, namely: the service is not operated for direct revenue; it is only an auxiliary in the railway business, and the nature of the traffic permits discriminations and very quick service. Since the telephone is a competitor with the railway telegraph and the railway mail, the economy of the telephone is interwoven with the cost of the telegraph and the mail. It is generally true of the traffic of communication that the volume of traffic decreases with the length of haul and that the bulk of the traffic is short haul.

The whole question of telephone service and its economy is secondary to the traffic, and the use of the telephone is justified when the traffic can be handled as cheaply in no other way and when the nature of the existing wire plant is such that to neglect the possibilities of simultaneous use is a waste. The traffic of communication by telegraph and mail should be thoroughly studied before it is decided whether the cost of telephone line construction is justified. The very short haul traffic is almost invariably handled most economically by telephone; the rapid increase in the use of private branch exchanges bears out this view. The inherent advantages of the telephone in this field are quick service and immediate answer or response; and in the class of communications of which no record is made these advantages are paramount.

Undoubtedly the mail, the telegraph, and the telephone are of relatively different economy under different conditions; but there is a class for each in which its economy makes it the superior method. It is important to keep records of the traffic of communication by these three methods, in order to see that each is handling the business which it is adapted to handle most cheaply.

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[1] Copyright, 1905, by Frank F. Fowle.

The railway mail probably constitutes the cheapest means of communication, and its peculiar field is not likely to be invaded until the advent of the printing telegraph. The natural tendency is to abandon the mail for the telegraph and the telephone, on account of the quicker service, and one of the uses of traffic records is to detect and prevent such abuses when the speed of the mail service is amply efficient. However, the mail service can never be better than the train service, and this point seemingly constitutes its limitation.

The entire traffic of communication is generally divisible into three main parts: the local or short haul, the traffic over each division or the moderate haul, and the traffic between the division offices and the main offices or the long haul. The volume of the long haul traffic depends very largely on the organization of the various departments, the distribution of the organization over the road, and the territory covered. The organization of the telegraph department will naturally be one conforming to the particular requirements of any case. There are two common features in nearly all organizations, namely: one train dispatching wire and one message wire, cut into all offices, over each division; if the division is long and the business heavy, it may be subdivided, because one wire cannot handle the traffic. The long haul traffic between division headquarters and the principal offices is usually handled on wires cut into few offices, and not infrequently these wires are duplexed or quadruplexed. The cost of telegraph service rests on considerations which are quite apart from those which determine the cost of telephone service. Before discussing the question of cost it may be well to define it, as considered in this paper.

What Constitutes Cost

Cost may be divided into two parts, operating cost and cost of ownership. Operating cost includes labor, power, light, heat, rent, and such supplies as are used in daily operation and not chargeable to maintenance. The cost of ownership includes the fixed charges on the entire plant, interest on first cost, depreciation, maintenance, insurance, and taxes; it is customary to compute these charges on a yearly basis and give to their sum the term Total Annual Charge.

The total yearly cost of ownership and operation is the sum of the Total Annual Charge and the Total Annual Operating Cost. This cost covers the entire plant, both line and terminals. There is obviously a division of cost between line and terminals which results in the best

economy; this division of cost may vary with the traffic conditions to be met, and the best economy will then be obtained by dividing the cost between line and terminals under conditions which satisfy the greater proportion of the traffic.

The Cost of Line Construction

All discussions of the comparative cost of construction are beset with the difficulty that the market prices of material and labor are constantly fluctuating. The average market price seems to be the only basis for comparisons which may be broadly useful; and that is the basis here used. The average price is further a safe basis in forming conclusions as to what proportion of future facilities should be included in the initial installation. As to this matter, it seems unwise to plan into the future further than the life of the vital portion of the plant — for obvious reasons.

Following a study of the expected traffic comes the question of how much will the line cost for a given volume (or loudness) of transmission. This question, like most others, is one of increasing cost with increasing efficiency; or in other words, for a given length of line, the louder the transmission desired, the more will it cost. Much has been said about standards of transmission, but the choice of a standard is a matter to be determined by the interests constructing the line and paying for the service. The engineer is concerned with this question only to show the *relation* between the volume of transmission and the cost.

Standards of transmission are usually defined as those over uniform circuits of particular construction, with only a standard telephone at either end. It is then possible, knowing the equivalents of cables and apparatus in terms of the standard circuit, to design transmission circuits to meet almost any commercial condition. Standards are very frequently stated in terms of open wire circuits of No. 8 B. W. G., and of cable circuits of No. 19 B. and S. G. The open wire lines are strung with the wires 12 inches apart; increasing the separation improves the transmission very slightly. The cable circuits are insulated with paper; increasing the capacity diminishes the efficiency. The K. R. law of transmission in cables is a simple and useful one; if R is the metallic circuit or loop resistance per mile and K is the capacity between the two wires per mile, the talking efficiency is inversely proportional to the square root of the product K. R. For example, to double the capacity and halve the resistance does not alter the efficiency. This law is inapplicable to open wire circuits.

High efficiency in open wire lines is secured by using low resistance wires; high efficiency in cable lines is secured by using low resistance wires and adopting a construction which will give the least capacity. The following table shows the weight of one wire per mile, for open wire circuits to talk various distances, on the assumption of several different standards: —

COPPER WIRE

Distance.	WEIGHT PER MILE, FOR A STANDARD OF No. 8 B. W. G. OF		
	850 miles.	1,200 miles.	1,800 miles.
Miles.	Pounds.	Pounds.	Pounds.
100	. .	. .	. .
200	. .	. .	. .
300	115	. .	. .
400	175	105	. .
500	230	150	. .
600	290	190	110
700	350	230	135
800	410	270	165
900	470	310	190
1,000	530	350	215
1,200	650	435	270
1,400	780	520	325
1,600	910	610	380
1,800	. .	695	435
2,000	. .	785	490

IRON WIRE, BB GRADE

100	180	. .	. .
150	450	210	. .
200	750	400	160
250	. .	610	270
300	. .	. .	400

The cost of construction may be computed on the basis of 15 cents per pound for copper and $3\frac{1}{2}$ cents for iron, and on the assumption that pin space is available on existing pole lines. There is also a charge against the circuit for its proportion of the original cost of right of way and the cost of poles, cross-arms, miscellaneous material, and labor; but this charge is practically independent of the questions at issue, and may be omitted from comparisons.

The cost of circuits in cable is determined by the prices of copper, lead, and tin, and by the method of construction adopted. The great advantage of the paper-insulated cable is the fact that its low capacity makes it very much less expensive than other types. Comparing rubber with paper on the basis that the rubber cable has about three times the capacity of the paper cable, the rubber cable will require more than three times as much copper as the paper cable, because the capacity increases with larger conductors; and rubber insulation is more expensive than paper. Paper insulation is undoubtedly the most economical for underground and permanent aërial work; rubber cable is justified only when its exposure is such that its superior insulating qualities are necessary and the extra cost may be regarded as insurance against service interruptions. Rubber insulation is superior for emergency cables and is often preferred for short submarine crossings. Paper cables are enclosed in lead sheaths to exclude all moisture and keep the paper perfectly dry. There is little advantage in sheathing rubber cables unless the thickness of rubber insulation is small and the cables are for submarine use. Aërial or underground rubber cables are usually covered with a layer of jute and then a braided covering.

Cables have been proposed with conductors insulated with rubber and then wrapped with paper; the advantages of this consist only in the advantages of rubber as an insulator, for the capacity will be practically that of conductors with insulation wholly of rubber. Cables have been proposed with the above arrangement reversed, the paper being applied first and then covered with rubber; such a cable will be more expensive than a paper cable, for a given efficiency. The capacity will be intermediate between that of a rubber cable and that of a paper cable. One of the advantages of the paper cable is that it may be laid up loosely, thus admitting air in the loose wrappings of paper and making the capacity even lower than a tightly laid up paper cable. It will be difficult to apply rubber insulation over the paper without compressing it and excluding the air.

Telephone cables are constructed in twisted pairs to avoid cross-talk; the length of twist varies from 3 to 6 inches. There is practically no additional cost over straight wire cables and they are equally efficient, with the advantage that conductors may be used as straight single wire circuits or as twisted metallic circuits.

The following table gives the mileage of No. 8 B. W. G. open wire circuit which is equivalent to one mile of circuits of various gauges in paper cables of ordinary construction: —

Cable Conductors.		Miles of No. 8 B. W. G. which are equivalent to one mile of cable.
Gauge B. and S.	Mutual capacity.	
		Miles.
22	.069 mf.	45.6
19	.054	28.5
16	.065	22.2
13	.065	15.7
10	.090	13.0

The cost of cables varies with a large number of conditions, but the following table shows the average cost in dollars per foot of cables, whose equivalents are given above: —

Number of pairs.	B. and S. Gauge.				
	No. 22	No. 19	No. 16	No. 13	No. 10
5	.037	.059	.073	.115	.148
10	.054	.083	.109	.175	.239
15	.061	.10	.139	.231	.331
20	.072	.12	. .	. .	. .
25	.083	.135	.194	.338	.492
30	.094	.15	. .	. .	. .
40	.109	.179	.273	.483	.734
50	.128	.21	. .	. .	. .

Thickness of sheath, $\frac{1}{12}$ inch.

The choice of the cable of the most economical efficiency in a given case depends on the standard of transmission, the length of open wire line, the length of cable, and the number of circuits. In any given case there is a particular gauge of line wire, taken in conjunction with a particular gauge and capacity of cable, which will give the desired transmission at the least cost. The cost per circuit, for both open wire lines and cables, diminishes as the number of circuits increases.

This question of the selection of the most economical gauge of cable applies equally to bridle, office, and switchboard cables; for example, the use of No. 22 B. and S. switchboard cable, in a line designed to talk 1,000 miles, is very expensive, because the same transmission could be secured with smaller line wire and larger cable at less cost. As a general rule, in cases where the burden of cost is in the open wire line, it is economy to use large gauge cables unless the cables are exceedingly short.

The terminal switchboard arrangements are also very important in their bearing on the efficiency of transmission. Petty savings on switchboard equipment are usually obtained at the sacrifice of efficiency, and it is very important to determine that the terminal talking circuits and apparatus are adapted to the line. A comparatively small investment in securing ample transmitter-battery power will improve transmission to the same extent that many times this investment, in increasing the size of the line wires, will improve it.

Simultaneous Use of Circuits for Telephony and Telegraphy

There is very great economy in the simultaneous use of trunk lines for telephony and telegraphy. There are two systems in common use: the composite system and the simplex system; the former secures two telegraph circuits from one metallic telephone circuit, and the latter only one telegraph circuit. The joint use is secured by introducing certain apparatus at the terminals, the character of which is generally well known. The insertion of this apparatus impairs the line efficiency, and joint use is not economy beyond the point where the investment in increasing the size of the line wires, to offset the loss of efficiency at the terminals, exceeds the cost of an additional circuit.

One terminal set of standard composite apparatus impairs transmission to the same extent as the introduction of approximately 1.25 miles of No. 19 B. and S. gauge cable or 35.6 miles of No. 8 B. W. G. open

line. The effect of two terminal sets would be equal to 71.2 miles of No. 8 B. W. G. Therefore it is economy to install composite apparatus in long trunk lines only, without intermediate telephone or telegraph stations.

In illustration of this, take the case of compositing a telephone line of No. 8 B. W. G. as compared with two No. 8 B. W. G. iron telegraph wires. The first cost of each circuit is given below, on the assumption that pin space is available on an existing line: —

Cost of Metallic Circuit of No. 8 B. W. G. Copper

870 pounds copper	at	$ .15	per pound	$130.50
80 pins	at	.01	each	.80
80 insulators	at	.02	each	1.60
80 tie wires	at	.025	each	2.00
10 sleeves	at	.035	each	.35
Labor	at	10.00	per mile	10.00
Total cost per mile,				$145.25

Cost of Single Wire Circuit of No. 8. B. W. G. Iron

378 pounds iron	at	$ .035	per pound	$13.23
40 pins	at	.01	each	.40
40 insulators	at	.02	each	.80
40 tie wires	at	.005	each	.20
Labor	at	5.00	per mile	5.00
Total cost per mile,				$19.63

The total annual charge on each circuit is computed below, on the basis of 4 per cent. interest, fifty-year useful life of copper wire and fifteen-year of iron; the annual cost of maintenance being principally the cost of labor, it is taken as $1 per mile of wire.

Annual Cost of Metallic Circuit of No. 8 B. W. G. Copper

Interest	at 4 per cent.	$5.81
Depreciation	at 2 per cent.	2.91
Maintenance	at $1.00 per mile of wire	2.00
Taxes	at 1 per cent.	1.45
Total annual charge,		$12.17

Annual Cost of Single Wire Circuit of No. 8 B. W. G. Iron

Interest	at 4 per cent.	$ .79
Depreciation	at 6.7 per cent.	1.32
Maintenance	at $1.00 per mile of wire	1.00
Taxes	at 1 per cent.	.20
	Total annual charge,	$3.31

The annual charge on the telephone circuit must increase $6.62 on account of compositing the circuit before it is economy to string two separate telegraph wires and work the telephone circuit uncomposited. This resolves itself into a question of the distance between telegraph stations. An increase of $6.62 in the annual charge on the telephone circuit may be regarded as the interest, depreciation, and taxes at 7 per cent. on the additional copper needed to maintain the efficiency of the telephone circuit. This amount capitalized is $94.57, and will pay for 630 pounds of additional copper, or a 750-pound wire instead of a 435-pound.

In designing a 1,200-mile line, on the 1,200-mile standard, it would be economy to introduce not more than six composited sections, giving telegraph service thereby between the two terminals and five intermediate telegraph offices. The economy of the composite is less apparent with a better standard of transmission; but the economy on short haul circuits of less cost is more apparent. The efficiency of the composite from a telephone standpoint exceeds the efficiency from a telegraph standpoint, for a telegraph circuit through twelve composite sets would not be satisfactory. The composite system is limited by the fact that an intermediate telephone station requires the same composite apparatus that is required at an intermediate telegraph station. Ringing over such circuits is accomplished by the use of special high frequency ringers. The question of economy may be summed up in the statement that the composite system is best adapted to circuits of moderate or great length, on which the telephone traffic and the telegraph traffic are of a through nature, or direct business between terminals.

The simplex system is somewhat more flexible, but does not present the same economy of line as the composite. There are two types of simplex apparatus, one of which employs a repeating coil and the other a bridged impedance; the latter is the more efficient. The repeating coil method is employed when grounded ringing generators may be connected to the line, which otherwise would ground the telegraph

circuit and chatter the relays; this method has advantages under certain conditions, but is not the most economical for long lines. The effect of a repeating coil of the most efficient type, introduced in the line at the terminal, is equivalent to the introduction of one mile of No. 19 B. and S. gauge cable, or 28.5 miles of No. 8 B. W. G. open line. The effect of the bridged simplex may be considered as equivalent to 0.25 mile of cable. Considering the former case of a 1,200-mile line of No. 8 B. W. G. copper, it will be economy to introduce simplex apparatus until the annual charge per mile of line exceeds $15.48; the increase of $3.31 capitalized at 7 per cent. is $48.14, and will permit increasing the weight of the wire to 595 pounds per mile. A 595-pound wire will talk 1,570 miles, and the margin over 1,200 miles is 370 miles of the 595-pound wire or 280 miles of 435-pound wire. It will be economy to simplex such a line, provided the number of simplexed sections does not exceed twenty. Intermediate telephone stations bridged on the line require no simplex apparatus, and this feature adapts the simplex system to short lines handling way (telephone) business. An intermediate telegraph station, at which there is no telephone, may be equipped with a repeating coil if the station is not near either terminal, because the introduction of an efficient coil has less effect if the coil is in the centre of the line.

The simplex system adapts itself to a greater range of traffic conditions than the composite, but it is especially adaptable to circuits handling way business, either telephone or telegraph. The Morse side of the composite system may be worked single or duplex, and on the simplex system it may be worked single, duplex, or quadruplex.

Circuits Wholly in Cable

For distribution from private exchanges the use of cable is economical if a considerable number of circuits follow one route. On the basis that it is not advisable from a mechanical standpoint to string copper wire weighing less than 150 pounds per mile, it follows that No. 22 gauge cable becomes economy for more than ten circuits, No. 19 gauge for more than fifteen, and No. 16 for more than twenty. This conclusion is arrived at on the basis that a circuit of 150-pound copper costs per mile: —

300 pounds copper	at	$ .15	per pound	$45.00
80 pins	at	.01	each	.80
80 insulators	at	.02	each	1.60
80 tie wires	at	.01	each	.80
10 sleeves	at	.025	each	.25
Labor	at	10.00	per mile	10.00
Total cost per mile,				$58.45
Total annual charge,				$6.09

The cost of aërial cable per mile is computed as: —

15-pair No. 19 Gauge Cable

5,280 feet cable at $.10 per foot	$528.00
5,280 feet supporting strand at $.01 per foot	52.80
3,000 cable hangers at $.005 each	15.00
40 suspension clamps at $.05 each	2.00
10 guy clamps at $.10 each	1.00
Labor	150.00
Total cost per mile,	$748.80

And the annual charge is computed on the basis: —

Interest	at 4 per cent.	$29.95
Depreciation	at 5 per cent.	37.44
Maintenance	at $15.00 per mile	15.00
Taxes	at 1 per cent.	7.49
Total annual charge,		$89.88
Total annual charge per mile of circuit,		$5.99

Cables of No. 13 and No. 10 gauge are suitable only for use in connection with long haul circuits, but are the most economical for such work. It is good practice to employ cables having conductors of several gauges, and such cables are in use, having No. 19, No. 16, and No. 13 gauge conductors.

If the cable had been compared with open metallic circuits of No. 10 B. W. G. iron wire, the point at which cable becomes economy would not have been reached for as low a number of pairs as in the case of the 150-pound copper circuit. The annual charge on the iron circuit of No. 10 B. W. G. is $5.54 per mile.

The use of loading coils for improving transmission, as shown to be

possible by Dr. M. I. Pupin, is of great economy for long circuits in cable. There is usually no advantage in loading circuits less than five miles in length, and loading should be confined to trunk lines. There are few railroad conditions where loading would be of material benefit at present. The loading of open wire lines is not advisable except for circuits of small gauge — and relatively low efficiency for long haul work. Considerable improvement may be obtained by loading such circuits. The improvement is obtained only for relatively long circuits, and the gain is not so apparent when such circuits are operated in short sections because of the harmful effect of bridges on the circuit at the intermediate offices.

The loading of large gauge, open wire lines is not advisable, because such circuits are already very efficient and because whatever improvement may be obtained is dependent on high insulation of the line; and low insulation not only impairs the efficiency of the loading, but so impairs it under the conditions of very poor insulation that the loading is a detriment to transmission.

Layout and Design of Circuits

The design of circuits to meet a particular set of conditions is a problem which may be solved with a precision equal to that in all ordinary engineering work, but it is essentially a traffic problem in the broadest sense. The terminal conditions are of the utmost importance, and have a great bearing on the line costs. In designing a long trunk line the various conditions which affect the efficiency of transmission should be carefully considered. The choice of the proper gauge of line wire cannot be decided until the equivalent effects on transmission have been determined for all the circuits and apparatus in the longest connection. The equivalents should be known for the sub-station lines, the switchboards, the office cables, the bridle cables, the underground, aërial, and submarine cables, and the composite or simplex apparatus.

The combinations of circuits in open wire with those in cable, and combinations of both with composite and simplex apparatus, are so numerous that they cannot be discussed here. The problem in general is that of selecting the combinations which make the total cost a minimum for a chosen standard of transmission.

The normal direction of telephone development is the construction of inexpensive short haul circuits initially, the moderate haul and long

haul circuits following in order with the growth of the telephone system. The bulk of the traffic being short haul, this represents an economical practice, since initial expenditures meet the greater part of the traffic. There are reasons for deviating from this, in the case of long trunk line railroads having business of a nature that demands the best means of quick communication between important trunk line centres or terminals. It is usually necessary in such cases to discriminate between users in order to prevent burdening the lines with moderate haul business.

A 1,200-mile standard of transmission over No. 8 B. W. G. circuits is probably ample for most long haul work. When the long haul traffic is light and originates at a limited number of telephones, it is economy to boost the transmitter batteries and to employ two receivers in order to save line copper. The use of two receivers materially improves weak transmission.

It is important to keep way stations off long haul circuits, and in general not to load short haul circuits with many stations. Permanently bridged stations are especially uneconomical if the traffic with them is heavy and they are connected to circuits of any length.

Use of Existing Wire Facilities

The existing wire plants of railroad systems offer an opportunity for considerable simultaneous use. The cost of reconstruction of straight telegraph wires into transposed pairs would permit of a double use of the wire plant, and it would be immediately available either for telephone or telegraph service. Further than this, an alternative means of communication is then available in case of failure of the telegraph service from any cause. It would also permit of dispensing with night operators in many instances, the small night traffic being handled by telephone. Iron wires are adequate for short haul service, and would relieve many of the existing telephone trunk lines of the burden of the short haul traffic.

The cost of reconstruction will consist largely of the renewal of bad joints and the insertion of transpositions. The following estimate is based on the assumption that there are eight joints and two transpositions per mile of circuit: —

Renewal of eight joints at $.25 each	$2.00
Two transpositions at .50 each	1.00
Total cost per mile of circuit.	$3.00

This would increase the annual charge on a pair of No. 8 B. W. G. iron wires from $6.62 to $6.94 per mile, the increase of 32 cents being 10.7 per cent. interest on $3. Such a circuit would furnish transmission equal to the 1,200-mile standard for 195 miles; for wires which have depreciated materially this might be reduced to 150 miles. Prior to transposing it, it will be necessary to measure the pole line carefully to determine the location of transpositions. Such work, done by three men at a rate of ten miles per day, should cost about $1.50 per mile of pole line.

Circuit Efficiency in Handling Traffic

The circuit efficiency (number of calls per day) increases with the number of circuits operated in a group to handle business over one route. The efficiency of a single circuit is usually low, but this has not been the experience in railroad work. Single trunk circuits are handling as many as 100 to 125 calls per day. As the volume of traffic over one circuit increases, the average delay on the traffic increases rapidly unless the circuit is one of a group of several circuits. Probably a traffic of fifty calls per day represents the largest traffic that can be handled without delay, giving first-class service. The use of the circuit to pass calls between the operators will occupy about 10 per cent. of the total time, leaving 90 per cent. of the hour for actual circuit use.

It is important from a traffic standpoint not to bridge intermediate way offices on busy trunk lines. Party lines are not economical except when the traffic per station is very small. If a station at some point on a through or trunk circuit has enough business to warrant telephone connection, it is usually the best plan to simplex or composite an iron circuit to the nearest office at which there is a private branch exchange. A busy station permanently connected to a trunk circuit is uneconomical of the line, if the line is of any considerable length.

The Operating and the Traffic Departments are usually large users of the telephone service, and properly so; the Supply Department may use the service to a considerable extent also. The other users should be restricted in order to place the service at the disposal of those in a position to make the best use of it.

The daily message capacity of a telegraph circuit is about 250 messages, on a nine-hour basis. Railroad messages are of much greater

average length than commercial messages, and are not usually condensed to the same extent. The same is true of telegraph circuits that is true of telephone circuits as regards the increasing delay with increasing traffic. For heavily loaded way circuits, under conditions where the way station attendant is a telegraph operator only incidentally, the telegraph probably handles the traffic as cheaply as it is possible to handle it, if the traffic per station is small.

The relative efficiency of the telegraph and the telephone is a very broad question, and one affected by many considerations. The following comparisons are based on a speed of conversation equal to four times the speed of Morse transmission. The average speed of conversation is 125 to 150 words per minute, and the average speed of Morse sending is thirty to forty words per minute. The traffic capacity of one telephone circuit is equal to four straight Morse circuits, two duplexes, or one quadruplex. The difference in labor costs is as follows: —

8 Morse operators	at $65.00 per month . . .	$520.00
2 telephone operators	at 30.00 per month . . .	60.00
Difference per month,		$460.00
Difference per year,		$5,520.00

The lower terminal operating costs in the case of the telephone offset a considerable annual charge on the more expensive line circuit. On the basis of a 1,200-mile standard of transmission the telephone is more economical than four straight Morse wires for distances up to 1,650 miles; it is more economical than two duplex Morse wires for distances up to 1,200 miles, and it is more economical than one quadruplex for distances up to 900 miles.

The economy of a simplexed telephone circuit, with the Morse side-working quadruplex, as compared with two quadruplex circuits, is such that it is the most economical arrangement for distances up to 1,200 miles or a trifle less than this if there are many intermediate exchange switchboards.

The conclusion is that economy in use of wire consists in building moderate haul telephone lines for simultaneous use, arranged to handle the long haul business by telegraph. When there are special uses for long haul telephone circuits they are no more expensive than Morse circuits, except for very long hauls — above 1,200 miles. On railroad lines where the traffic of transportation is light or moderate, and where

one train dispatching circuit and one combined business and commercial circuit are sufficient, the business can be handled most cheaply by telegraph. The very long haul traffic also can be handled by telegraph most cheaply. On railroad lines where there is heavy transportation traffic it is usually the case that the traffic of communication is correspondingly large; and this is the economic field of the telephone, worked simultaneously with the telegraph.

Records of Traffic and Wire Trouble

Traffic records are of value — as applied to the mail, the telegraph, and the telephone — in preventing abuses of the service and keeping the various classes of traffic in their respective channels, in detecting parts of the wire plant which may become idle through changes in organization or traffic methods, and in ascertaining when circuits are overloaded and additional facilities needed. Telephone traffic records should show date, time, origination, destination, reason for delay, length of connection or for what reason it was not established, and the names of the parties or departments. Telegraph traffic records should show the date, time received, filed, and transmitted at the origination; at the destination should be shown the time received, filed, and delivered. Mail records should show the date, origination, destination, train number, and the departments between which the communication passed.

Traffic summaries should be prepared in two ways, one showing the daily message load on each office and the other the daily message load on each circuit.

Records of wire trouble are useful to show causes for traffic delays and also to detect bad construction, bad line conditions, or lack of prompt location and removal of trouble.

Line maintenance is an important question, and it is economy to employ a force sufficient to clear trouble promptly. Trouble on trunk lines and long circuits should be cleared before local office troubles if there is necessity for a choice. If a 100-mile circuit is in trouble, on which the total annual charge is $10 per mile or a daily charge for 100 miles of $2.74, it is obviously economy to get the section lineman to the trouble very promptly. This point is more strongly emphasized by the attendant delay to traffic and congestion of business.

Crossings with High Tension Power Transmissions

The growing commercial importance of transmitting power electrically over transmission lines operated at pressures as high as 33,000 volts — and in the far West even higher — emphasizes the danger of such lines. The general question of the joint occupancy of pole lines and subways by telephone, telegraph, and power systems is well set forth in the "National Electrical Code" of the National Board of Fire Underwriters. Class E, "Miscellaneous," Rule 64, on "Signalling Systems," and Class B, "Outside Work," Rule 12, on "Wires," and Rule 12A, on "Constant-Potential Pole Lines, over 5,000 Volts," apply to all telephone and telegraph work. The telephone companies are making extensive application of various methods for protecting aërial crossings with high tension lines. Some of these methods have been described in the technical press (*Electrical World and Engineer*, May 21, 1904, by Robert E. Chetwood, Jr.) and are well worth using where the conditions permit them. Standardization of crossings is not feasible on account of the wide range of conditions to be met, but there should be a universal policy in regard to providing screens between the lines or going underground with one line, and also in regard to the minimum mechanical strength of wires, poles, cross-arms, pins, and insulators.

Existing Railroad Telephone Systems

The following railroad systems have extensive telephone systems, including lines of considerable length: New York Central and Hudson River Railroad, Lake Shore and Michigan Southern Railway, Illinois Central Railroad, Lehigh Valley Railroad, New York, New Haven and Hartford Railroad, Delaware, Lackawanna and Western Railroad, Chicago, Burlington and Quincy Railway, Pennsylvania Railroad, Pennsylvania Company, Chesapeake and Ohio Railway, Baltimore and Ohio Railroad, Northern Pacific Railway, Pittsburg and Lake Erie Railroad, and Long Island Railroad.

The largest gauge wire is No. 8 B. W. G. and the smallest is No. 10 B. and S., for aërial work. Considerable use of composite and simplex systems is made. The longest transmission is from New York to Chicago, 960 miles, over the New York Central and Hudson River Railroad and the Lake Shore and Michigan Southern Railway. The total mileage of telephone circuit is approximately 6,000 miles, excluding very short lines and station circuits.

APPENDIX — WIRE TABLE

Weight per mile of copper wire.	Gauge.		
	B. and S. G.	B. W. G.	N. B. S. G.
Pounds.	No.	No.	No.
10.2	22	. .	. .
12.5	. .	22	22
13.0	21	. .	. .
16.4	20	21	21
19.6	. .	20	. .
20.7	19	. .	20
25.6	18	. .	19
28.2	. .	19	. .
32.0	17	. .	. .
36.8	. .	. .	18
38.4	. .	18	. .
42.0	16	. .	. .
50.0	. .	. .	17
52.0	15	. .	. .
54.0	. .	17	. .
65.0	14	. .	16
68.0	. .	16	. .
83.0	13	15	15
102.0	. .	. .	14
105.0	12	. .	. .
110.0	. .	14	. .
132.0	11	. .	. .
135.0	. .	. .	13
144.0	. .	13	. .
166.0	10	. .	. .
173.0	. .	. .	12
190.0	. .	12	. .
208.0	9	. .	. .
215.0	. .	. .	11
230.0	. .	11	. .
262.0	8	. .	10
287.0	. .	10	. .
331.0	7	. .	9
350.0	. .	9	. .
409.0	. .	. .	8
419.0	6	. .	. .
435.0	. .	8	. .
495.0	. .	. .	7
518.0	. .	7	. .
529.0	5	. .	. .
589.0	. .	. .	6
659.0	. .	6	. .
665.0	4	. .	. .
718.0	. .	. .	5
777.0	. .	5	. .
838.0	3	. .	. .
860.0	. .	. .	4
905.0	. .	4	. .
1,064.0	2	. .	. .

THE LIMESTONE-GRANITE CONTACT DEPOSITS OF WASHINGTON CAMP, ARIZONA[1]

By W. O. CROSBY

Introduction

Washington Camp, in Santa Cruz County, Arizona, is a small and little known mining district situated on the lower eastern slope of the Patagonia Mountains, about twenty miles east of Nogales and a like distance south of Patagonia station on the Sonora Railroad, which connects at Benson, eighty-three miles from Nogales, with the main line of the Southern Pacific. This district is also about four miles north of the international boundary, thirty-five miles west of Bisbee, and forty miles north of Cananea, in Sonora. The topography of the district, which lies at a general elevation of 5,500 feet above the sea, is only very moderately rugged, and presents no obstacles to mining operations.

Although some of the claims of the camp, including the Pride of the West, Belmont, and Holland, were extensively worked for silver twenty-five years ago, they passed, at moderate depths, as in so many other districts, out of the argentiferous lead carbonate and sulphide into zinc, copper, and iron sulphides; and for two decades the camp was abandoned and almost forgotten. In recent years, however, its apparent possibilities as a copper producer have led to a revival of mining activity, but not as yet with conspicuous success.

Although economically relatively unimportant, the deposits of Washington Camp are, mineralogically and structurally, nevertheless, typical examples of ore bodies developed in connection with the garnet ledge now recognized as a normal feature of granite-limestone contacts; and in the opinion of the writer this is an instance where a minor example is yet essentially normal and capable of throwing important light upon the origin and genetic relations of the type.

[1] A paper presented to the American Institute of Mining Engineers at its meeting in Victoria, B. C., July, 1905, and published in the Technology Quarterly by arrangement with the Council of the Institute.

I visited Washington Camp in 1901 and again in 1902, and have devoted in all about a week to the study in the field of the geologic relations of its ore deposits, adding, incidentally, a suite of the rocks and ores to the economic geologic collections of the Massachusetts Institute of Technology.

General Geology

Washington Camp consists (geologically) of an irregular area of limestone and quartzite of uncertain age, some 7,000 feet in extreme length north and south, and 3,000 feet in maximum breadth east and west. This body of sediments is bordered on all sides by igneous rocks — granite and porphyry; and it may be regarded as an island in the sea of granitic rocks composing the main part, at least, of the Patagonia range. The granite and the porphyry (which is clearly a somewhat later phase of the granite) are newer than the sedimentary rocks, and have been erupted through the latter; and the area in question is simply a remnant of the original formation which was so deeply engulfed by the igneous rocks that it has survived the extensive erosion which has long since swept away the rest of the sedimentary cover of the granite over an area of many hundreds of square miles. That the erosion has been extensive we have also positive proof in the highly crystalline character of most of the granite and in the highly metamorphic character of the limestone, even at points remote from the border of the granite. The sedimentary rocks are not now absolutely continuous, but several detached masses occur in the granite along the eastern border of the main area; and the latter is more or less completely divided towards its western margin by several large north-south dikes of granite. Although no fossils have survived the metamorphism of the limestone by which its geological age might be determined, there is no reason to doubt that it is a part of the great Paleozoic limestone formation so characteristic of many of the mining districts throughout the entire Rocky Mountain region.

The strata are highly inclined at all points, but the dip varies greatly in direction and amount; the prevailing dip, however, is to the west at angles of from 30° to 90°, but mostly above 60°; while toward the eastern border the dip, at a few points, is reversed, or easterly, at similarly high angles; and in general it may be said that the stratification is highly disturbed, with, in some cases, abrupt and extreme variations in strike and dip.

Beginning on the west side of the belt, we have: First, a band of quartzite from 100 to several hundred feet wide, which may tentatively be regarded as of Cambrian age. Following this and magnificently developed in Washington Mountain, the highest point in the district, is a massive limestone, characterized by numerous narrow bands and lenses of chert. Dividing the limestone on the eastern slope of Washington Mountain is a second band of quartzite at least 100 feet thick. This is followed by a broad band of blue, crystalline limestone, or marble, extending well down toward the base of the mountain. Still farther east this limestone is interstratified with one or more heavy beds of chert, which, having commonly a somewhat crystalline character, are usually called quartzite. On the eastern slope of the mountain are also to be seen the great dikes of granite, three in number, previously referred to, the most easterly of these dikes forming the hanging wall of the Pride of the West Mine. This brings us approximately to the middle of an east-west section of the sedimentary series; but farther east the limestone is comparatively free from chert bands, presenting extensive bodies of gray to white crystalline marble in which the stratification is often very indistinct.

It thus appears quite certain that the section is not repeated or folded upon itself; and, notwithstanding the prevailing westerly dip, it is probable that the western quartzite is the oldest member of the series; and the entire formation may, therefore, be regarded as partially inverted.

The sedimentary series is apparently conformable throughout; and one is tempted to correlate the western or assumed basal quartzite of the Washington Mountain section with the Bolsa quartzite of the Bisbee district, described by Ransome.[1] The latter, however, with a maximum thickness of 430 feet, is seen to rest uncomformably upon the Pinal or Algonkian schists; while the former, though not so thick, is everywhere in igneous contact with the granite, and it is improbable that its full normal thickness is now exposed. The limestone following this quartzite and forming the main mass of Washington Mountain becomes, then, the equivalent of the Abrigo limestone of Bisbee, which has a thickness of 770 feet. These two limestones are certainly comparable in thickness, and in the prevalence of chert; but the Washington Mountain limestone is more massive and apparently non-fossiliferous,

[1] Folio 112, United States Geological Survey.

due possibly to more intense metamorphism; while the Abrigo limestone is definitely proved by its fossils to be of Middle Cambrian age. In each district this older limestone is followed by a second white quartzite; but this is only 8 feet thick at Bisbee and fully 100 feet on the eastern slope of Washington Mountain. Above this quartzite, at Bisbee, come several thousand feet of limestone, including the Martin limestone (Devonian), 340 feet; the Escabrosa limestone (Lower Carboniferous), 800 feet; and the Naco limestone (Upper Carboniferous), 1,500 to 2,000 feet. These upper Paleozoic limestones of Bisbee may, perhaps, be correlated tentatively with the Washington Camp section above the parting quartzite; and I have been inclined to regard the latter as a general equivalent of the Harding sandstone in Colorado.[1] The heavy beds of chert in the middle part of the Washington Camp section appear to be wanting at Bisbee.

From the northwest border of the area of sedimentary rocks, at least three great dikes of granite extend southward along the strike of the limestone. The most easterly dike, fully 100 feet wide, forms the hanging wall of the upper ore body in the Pride of the West Mine, and is separated by several hundred feet of chert and limestone from the second dike, which is proved by a crosscut tunnel to be over 150 feet wide. These two dikes converge southeastward and become one. The united dike can be traced across Double Standard Gulch, passing west of the Holland Mine; and it probably continues until it crosses the southern border and rejoins the main body of granite on the Belmont claim or the Lead King claim. The second dike, on the eastern slope of Washington Mountain, is separated by a broad band of blue, crystalline limestone and the parting quartzite from the third dike, which is at least 100 feet wide, but appears to die out southward before reaching Double Standard Gulch. Above this dike the very massive crystalline limestone, with innumerable lines and lenses, but no heavy beds, of chert, extends to the summit and to the contact with the basal quartzite on the west slope.

In further comparison with the Bisbee district, it may be noted that the garnet ledge is more prominently developed than at Bisbee, and that faulting is relatively unimportant at Washington Camp, so that there appears, in general, to be little difficulty in tracing a particular horizon from end to end of the sedimentary island or inclusion in the granite.

[1] Folio 7, United States Geological Survey.

The granite varies from a normal biotite granite to a well-characterized granodiorite, with dikes, also, of a highly acid, aplitic variety. The porphyry seems to show a similar range in composition, and occurs chiefly, at least, as dikes, cutting both the granite and the sedimentary rocks, although probably essentially contemporaneous with the former.

The metamorphic influence of the enclosing and intrusive acid igneous rocks is seen, not only in the crystallization of the limestone to form marble, and of the chert bands to form quartzite, but also, and very strikingly, in the development in the less pure layers of the limestone of enormous bodies of green garnet (grossularite) and other secondary silicate minerals. The original limestone may safely be assumed to have contained silica, clay, and iron oxide as the chief impurities; and from the more impure beds of limestone, during the process of metamorphism, the garnet zones have been developed. These zones are commonly from 50 to 100 feet or more in breadth; and they are found, not only along the limestone-granite contacts, but also running in a north-south direction through the middle of the limestone remote from the granite wherever, we may suppose, the original composition of the limestone favored their development, and chiefly along lines passing longitudinally through the Pride of the West, Holland, Double Standard, and Annie belts of claims. The garnet rock, again, is not a constant feature of the contact, its absence at the north end of the district, on the eastern border, and across a part of the south end, as also, in general, along the granite dikes, being especially noteworthy; but it is, apparently, developed only where the limestone was sufficiently impure to furnish in both quality and quantity the material required for the formation of the garnet and related minerals. This selective relation is particularly obvious at the south end, where the contact cuts squarely across the strike of the limestone, and the garnet zone is developed only on the less pure beds of limestone. It is a very significant fact in this connection, or in its bearing upon the origin of the garnet zone, that along that part of the western border of the district where the basal quartzite intervenes between the granite and limestone the garnet zone is found between the quartzite and limestone, and not along the contact of the quartzite and granite.

The granitic rocks not only completely surround the sedimentaries, but at some depth they must underlie them, so that a vertical shaft at any point would eventually pass out of the limestone into the granite; and it is altogether reasonable to suppose that this lower

contact, at least equally with the lateral contacts, is characterized by the garnet zone.

The fact that the metamorphism of the sedimentary rocks is not confined to the borders, but is, in general, somewhat uniform over the entire area, varying only with the original composition of the limestone, and the absence, at most points, of a fine-grained or compact border in the granite itself, show, not only that these rocks were very deep-seated at the time of the intrusion of the granite, but also, apparently, that the granite underlies the limestone now at no very great depth, although the Westinghouse shaft, on the extreme eastern margin of the limestone, has failed to reach the bottom at a depth of 650 feet.

Ore Deposits

Although having, in general, more or less the forms of veins, the ore deposits are not, to any important extent, true veins, but are better classed as substitution deposits or replacements in the limestone. Among their most striking characteristics are:—

First, they are entirely confined to the sedimentary rocks, and chiefly to the limestone, and have not been observed in any instance to extend never so slightly into the surrounding granite. This seems to force upon us the conclusion that the ores have not been derived from the granitic rocks, and have not come from a great depth in the earth.

Second, save where the contact is transgressive, they correspond closely, but not always exactly, with the limestone in dip and strike, and are at all points clearly to be recognized as replacements of the limestone.

Third, where not accompanying the limestone-granite contact, they usually occur along the contact of the limestone with a principal bed of chert.

Fourth, they are, in general, very intimately associated with the garnetiferous zones, which undoubtedly represent what were originally exceptionally impure members of the limestone series. This association is so constant that the garnet has come to be recognized as a fairly reliable indication of the occurrence of the ores; and the garnet rock and the ores are often very intimately commingled, the garnet forming in most cases the principal gangue of the metalliferous minerals or ores.

Fifth, the ore body accompanying a contact garnet zone is always

on the *inside* of the zone, that is, between the main body of the garnet ledge and the limestone, and not between the garnet ledge and the granite.

The ores include chiefly chalcopyrite and sphalerite, with, at the present time, very subordinate amounts of galena. Secondary ores are relatively very unimportant, and are now pretty well worked out. The oxidized copper ores, including cuprite, the carbonates, and chrysocolla, occur but sparingly, and the secondary sulphides (bornite and chalcocite) are rarely seen. Although the copper ore (chalcopyrite) ranks first in value at the present time, the zinc ore (sphalerite) predominates in the deposits, tending to become relatively more important with depth; and an important output of zinc would seem to be among the possibilities for this district.

Metamorphism of the Limestone and Chert

The crystallization of the purer phases of the limestone to form white to gray saccharoidal marbles and of the chert (in part) to form non-clastic quartzite are normal phenomena, demanding no special discussion. In part, however, the metamorphism of the chert has gone far beyond the degree here indicated. Thus, in the southwestern part of the field, on the Lead King and Belmont claims, bordering but not penetrating the granite, is a compact body of coarsely crystalline quartz, fully 100 feet wide and extending northward, in the direction of the strike and away from the granite, at least 300 feet, and possibly much farther. In large part this body is essentially structureless, consisting of massive, vitreous quartz, but enclosing, also, many more or less distinct crystals of quartz, ranging in size up to at least 2 feet in length and 5 inches in diameter, and occurring to a considerable extent in radiate groups. A shaft sunk 20 feet into this mass disclosed nothing but pure quartz in a plexus of gigantic crystals. The outcrops in this part of the field are less continuous than could be desired; but the facts clearly indicate that this remarkable body of nearly pure crystalline quartz is not in any sense a vein or a pegmatitic phase of the granite, but rather that it marks an extreme degree of metamorphism of a broad band of chert, the quartz being in the line of strike of such a chert horizon and seeming to grade longitudinally into it. Although an extreme, it is by no means an exceptional or unparalleled, phase of the metamorphism, except, perhaps, in the

magnitude of the resulting body of crystalline quartz, for coarsely crystalline quartz, sometimes in stellate groups, is a constantly recurring feature of the garnet zones and ore bodies; and it is probable that a detailed study of other chert bands in the vicinity of the granite would show that a gradation from the normal to the most highly metamorphic forms of the chert is a general fact. Unfortunately, no economic interest attaches to the chert, and hence exploitation has added but little to our knowledge of its occurrence.

No correspondingly coarse crystallization of the limestone on a large scale has been noted, although near the igneous contacts and in the garnet zones it is commonly distinctly sparry, with cleavage faces of calcite one to several inches across. The chief interest of the metamorphism of the limestone is found, of course, in the secondary minerals, among which the pale yellowish- or brownish-green lime-alumina garnet (grossularite) largely predominates in finely to coarsely crystalline massive aggregates. The form is dodecahedral, and the individual crystals rarely exceed 2 inches, and are commonly less than $\frac{1}{4}$ inch, in diameter. Associated with the garnet, in some parts of the field, is more or less epidote in slender, green prisms, with possibly some vesuvianite and various forms of amphibole, including actinolite and tremolite, the latter being most abundant and often very intimately associated with the ores. Quartz in coarse and irregular masses is usually, as previously noted, rather a prominent feature of the garnet ledge, which, because of the hard and resistant character of its component minerals, forms bold and rugged outcrops, made, in detail, more rugged by the solution of the included sparry calcite and the weathering out of the ores. The crystalline iron ores (magnetite, etc.) and the jasperoid forms of silica, often associated with the garnet zones of other districts, are practically wanting in Washington Camp.

A rather specially interesting phase of the metamorphism of the limestone, though not as yet identified as a feature of the garnet ledge or the ore bodies, is massive lime silicate or wollastonite, occurring commonly as a reaction zone bordering layers and nodules of chert in those portions of the cherty limestone nearest the granite, or within several hundred feet of the contact. The relations are very clear, the chert masses, often with frayed and disintegrated margins, being separated from the enclosing crystalline limestone (white marble) by zones 1 to several inches broad of the white and massive wollastonite, which, like the chert, is left in high relief on the weathered surface

of the limestone. That the silica of the chert has replaced the carbon dioxide of the limestone is very obvious.

The geologic interest of the metamorphism of the limestone centres in the source of the materials of the garnet and other secondary silicates. Although some recent writers have regarded the garnet zones as intrusive igneous masses or, possibly, as differentiation products of the granite magma, the general consensus of opinion at the present time is that they are normal products of the contact metamorphism of the limestone. No other view can be made to fit the facts of Washington Camp; and the question of vital interest is as to whether the limestone has furnished all or only a part of the ingredients of the garnet and other silicates, the necessary elements being approximately the same for them all. It is a significant fact that they are practically all lime silicates; and apparently no one accepting the metamorphic theory doubts that the lime is wholly indigenous, that is, was furnished exclusively by the limestone. All the other required elements are normal impurities of limestone, including silica, alumina, magnesia, and iron. The first two, with a little iron, suffice for garnet and epidote; and the addition of the magnesia makes the amphiboles a possibility. It is certainly a very exceptional limestone which does not contain the small amount of magnesia which this case calls for; and surely we have no need and no warrant to go outside of the limestone for such a normal, abundant, and stable or insoluble impurity as alumina. The *onus probandi* clearly rests upon those who hold to the contrary view. Similarly, ferrous carbonate, not to mention the oxides and sulphides of iron, is a nearly universal constituent of limestones and a ready source of iron for the metamorphic ferruginous silicates, as well as for magnetite and sparry siderite.

Finally, silica, including free silica, both clastic and organic, and the combined silica of kaolin and other silicates, is perhaps the most important of all the non-essential elements of limestone. The ratio of silica to alumina in kaolin is less than in grossularite; but original free silica may easily make good the difference, and any excess of lime may or may not be eliminated by solution. The sufficiency of the free silica is indicated by the fact that in many analyses of limestones not visibly siliceous the total silica is far in excess of the amount required to form kaolin with the alumina. The averages of forty-two analyses of limestones made in the laboratory of the United States Geological Survey and published in Bulletin No. 228, including all those for which both the

silica and alumina are given separately, are: SiO_2, 8.514 per cent., and alumina, 1.077 per cent., the ratio being very nearly 8 : 1.

Analyses of unaltered limestone are, of course, devoid of special significance in this connection, unless it can be shown that they represent closely adjacent portions of the same beds which have locally suffered metamorphism by silication. Limestones more than most other kinds of sediment are, in successive beds, subject to marked and abrupt changes of chemical composition, due to fluctuations in the proportions of the normal (organic) and the accessory (organic, clastic, and chemical) constituents; and gradations into beds of chert, shale, and even sandstone are not uncommon.

In view of these considerations, further argument might almost be deemed superfluous, at least as regards the adequacy of the limestone considered as a source of the raw materials of the contact minerals. But some of the arguments based upon the structural relations of the limestone are also peculiarly cogent. For instance, the garnet zone is, as previously noted, by no means a constant accompaniment of the granite-limestone contact; and in strength and persistence it obviously varies inversely as the purity of the limestone, being very weak or wholly wanting where the purer beds of limestone, the typical white or light gray marbles, meet the granite. This selective relation is very noticeable across the ends, and especially the broad southern end, of the limestone island, where the granite contacts successive beds of limestone of varying composition, and fails to develop a garnet zone wherever the limestone is of notable purity. Besides the variable and intermittent character of the garnet zone along the contact, we must take cognizance of the very persistent garnet zones which, disregarding the granite contact, follow each a particular bed or horizon of impure limestone longitudinally through the district; and of special interest and significance among these is the garnet zone at the base of the limestone, in the siliceous and argillaceous beds of passage between the basal quartzite and the limestone, and separated by the quartzite, 100 to 200 feet thick, from the western granite.

Among those who accept the metamorphic origin of the garnet zones of granite-limestone contacts, Professor Kemp is the foremost exponent of the view that the granite has contributed, not only the heat or thermal energy, but also in large part the material required for the formation of the garnet and related silicates. Apparently Professor Kemp would look to the granite or acid plutonic for everything need-

ful, except, perhaps, the lime; although it may be noted that the plutonic rock is, in general, rich in lime as well as alumina, and the transfer of the former base would be the simpler chemical problem. However, the lime is not needed, and in the opinion of the writer it has not been proved that we need look beyond the sedimentaries for any of the raw materials of the garnet zone. To simplify the phraseology and at the same time to emphasize the vital contrast of the two explanations of the garnet zone now under consideration, we may restrict the term *metamorphic* to the theory which derives all the material from the limestone and refers to the granite only for the agents — heat and possibly some water; and designate as *metasomatic* the theory which derives an important and essential part of the material, as well as the agents, from the granite.

Except where the limestone is very impure, the lime will naturally be in excess of the amount required to form the garnet and other secondary lime silicates; but that this is in no sense a bar to the metamorphic theory must be obvious when we consider the possibility of disposing of the excess by either contemporaneous or subsequent solution or recrystallization. An instructive illustration on a minor scale is offered by the writer's observations on the calcareous Lower Cambrian slates of the Boston Basin. In this instance the calcareous element assumed originally the form of calcareous concretions or clay stones; and when, in later Paleozoic times, the strata were invaded by the granitic series and suffered metamorphism, the outer part of each calcareous concretion became a shell of impure epidote. In many cases the silica and alumina within this shell have been exhausted in the formation of the epidote, and the residuary calcium carbonate has recrystallized, forming a core of white marble in the epidotized calcareous concretions of a red slate.

Regarding the granite as an important or, possibly, principal source of the materials of the garnet zone, as we may for the sake of the argument, gives the contact relations and character of the granite special significance and interest, since it is not easily credible that the granite might transfer to the limestone a large part of the material of the garnet zone and still remain entirely normal, giving no sign of its loss. As a matter of fact, both the granite and porphyry, so far as can be determined by macroscopic observations, are unchanged in texture and composition and entirely normal on and near the sharply defined line of contact. In other words, the granite shows no reaction

zone, and there is absolutely nothing to suggest the leaching, depletion, or mineralization of either formation by, or at the expense of, the other. These statements are applicable alike to the main body of the granite and to the granite dikes.

If the silica and alumina have been derived from the granite, and the limestone has furnished only the lime, magnesia, and iron, the garnet zone should be a constant feature of the contact; or, at least, there is no apparent reason why it should fail, as it does, just where silica and alumina are wanting in the limestone. Again, the metasomatic theory affords absolutely no explanation of the essentially similar and equally strong garnet zones developed independently of the granite contacts in the limestone or between the limestone and the basal quartzite, for surely we cannot suppose that material in liquid or gaseous solution would pass through hundreds of feet of solid limestone or quartzite to react with the limestone of certain definite and narrow horizons.

Professor Kemp has minimized the normal ground water of oceanic and meteoric origin, and maximized the magmatic water emanating from plutonic and intrusive magmas before and during refrigeration, as regards both volume and geological efficiency, and especially as regards their efficiency in the formation of veins and ore deposits. The only definite and positive indication that the magmatic water is abundant is offered by the copious exhalations of steam accompanying volcanic eruptions. But the argument that this is all, or even chiefly, magmatic water is far from conclusive. Its deposits certainly do not indicate it. A distinguishing feature of magmatic water is supposed to be its heavy burden of dissolved elements, which, combined to form various mineral species, must be left behind, on or in the lava, as the water escapes into the atmosphere. Except, perhaps, in, or in the immediate vicinity of, vents of long-continued solfataric activity, these deposits are usually conspicuous by their absence. The water promotes the liquidity of the lava, and thus, in a sense, holds in solution the entire body of the magma, and although diminishing with the pressure, like the gases dissolved in molten metals, it manifests no marked tendency to escape in advance of the general refrigeration of the magma; and then, in general, it leaves behind no deposit other than the normal lava.

The argument for the sufficiency of magmatic water requires us to assume that below the superficial, shallow, and wet zone of the vadose

circulation in the earth's crust is a deep and relatively arid or anhydrous zone, the upper part of which has been discovered by numerous mines and borings; and below that, in the plutonic regions where magmas are developed, a third zone which, like the vadose, is highly hydrated, but the water of which is original, or primitive, and has never formed a part of the hydrosphere. The intermediate, relatively dry zone, comprising the main body of the earth's crust, is composed, for an average thickness to be measured by miles, of sedimentary rocks, which must have once been in a state of supersaturation, but which have suffered extensive dehydration under the combined influence of long-continued heat and pressure. How it is that the water of the plutonic zone, exposed for an immensely longer time to far higher temperature and pressure, has escaped expulsion has not been explained. Further, it is virtually asserted that the volcanic chimney belongs to that bad class which will not "draw"; in other words, that the subterranean chimney does not create an indraught of the ground water analogous to the indraught of air to a subaërial chimney. This anomaly, if true, also awaits explanation.

For the magma the conditions are dominantly thermal, but for the resultant lava they are, or soon become, dominantly aqueous. The component minerals then prove to be more or less unstable compounds, and are subject to alteration by the indrawn ground water, the solvent and decomposing actior of which is promoted rather than retarded by the high temperature still prevailing. In other words, solfataric waters, by which alone important deposits are made within the range of observation, are probably not chiefly magmatic waters struggling up from plutonic depths, but rather they are to be regarded as marking the first and most vigorous attack of the normal ground water upon the intrusive and effusive igneous rocks, and hence as positive proof that the chimney does draw at this stage, if not earlier.

In any speculation as to the volume of water set free by the freezing of a magma under plutonic conditions, it is important not to forget the shrinkage due to crystallization and cooling, or that the liberated water, though above the critical temperature, may yet have the density of the liquid, or that there exists a real affinity between this water and the magma residuum, as so clearly proved by the phenomena of pegmatite. It is the excess water, if there be any, that concerns us now; and its natural avenue of escape, it would seem, should be upward rather than lateral.

The picture of a copious exudation of magmatic water which, reënforced by various mineralizers and overladen with a large variety of elements, actively invades and alters the enclosing terranes by metamorphic and metasomatic processes is not easily visualized, in view of the plain, every-day facts of the case In the vicinity of Boston, and extending throughout eastern Massachusetts, the coastal district of New England, and the Maritime Provinces, are miles on miles, literally hundreds of miles, of contact of granitic rocks, not to mention a vast network of acid and basic dikes, intrusive in Cambrian and other early Paleozoic sediments. These sediments exhibit various degrees and kinds of metamorphism; but very seldom indeed do we find in them elements which may not fairly be regarded as original. Fluorite and other minerals regarded as specially indicative of the presence and agency of the so-called mineralizers are found chiefly in the igneous rocks, and have not migrated into the sediments. Apparently, heat is the one important contribution of the igneous rocks; and the normal ground water, stimulated or energized by this heat and acting on the original elements of the sediments, has done the rest. Even quartz veins and segregations are but rare accompaniments of the plutonic contacts of this region, and where occurring may usually be proved to antedate (as in the case of the auriferous veins of Nova Scotia) or postdate the development of the contact.

Especially difficult of visualization is the picture of the magmatic water gushing forth in so great volume that by the deposition of its excess load merely it may build a garnet zone 100 feet thick, equal to 100 cubic feet of garnet and the emission of many thousand cubic feet of water for every square foot of the contact. The magma must, indeed, be highly hydrated to meet such a demand, and yet it is now of strictly normal character up to the sharply defined contact.

The development of the garnet zone, whether by metamorphic or by metasomatic process, must have been centripetal with reference to the limestone, at least if we are to look to the limestone for the lime, necessitating, according to the metasomatic theory, the transfer of the silica and alumina and other imported elements required for the inner part of the zone through the outer part. Also, the refrigeration or crystallization of the magma to form the granite must have proceeded centripetally, or away from the contact, thus opposing a barrier of steadily increasing thickness to the emission of the magmatic water. In other words, the water liberated by the crystallization of the magma

is forced inward, where it is needed to maintain the fluidity of the magma residuum.[1]

Origin and Relations of the Ore Deposits

The ore deposits of this district clearly belong to certain more or less well-defined zones in the limestone, which may or may not follow granite-limestone contacts, but which are, in general, characterized by a more or less marked development of the garnet ledge. The relations of the ore bodies to the garnet zones are very intimate and irregular, and the garnet and other secondary silicates, together with a limited amount of quartz and sparry calcite, constitute the normal gangue of the ores. But although we may regard the garnet ledge as in a general way favorable to the occurrence of ore, some important ore bodies are devoid of garnet; and the garnet zones are at some points devoid of ore, or the ore occurrences are very limited and sporadic. Where associated with garnet zones following the granite-limestone contact, the normal position of the ore, as previously stated, is clearly on the inner margin of the zone, facing the limestone and not the granite. The ore bodies are practically never vein-like in form or structure, and they are devoid of true walls, since they clearly antedate all shearing and fracturing of the formation. The contact of the ores, alike with the limestone and the garnet, is often sharply defined, but always highly irregular; and in the association or grouping of the ores there is nothing remotely suggestive of crustification, banding, or comb-structure, or deposition in open spaces of any kind. Obviously enough, the ores as we now have them are due to a metasomatic impregnation and replacement of the limestone against and in the massive garnet ledge, and the questions of special geological interest are, whence and how; that is, what is the original source of the ores and how were they concentrated?

We cannot avoid the conclusion that the ores have come from either the limestone or the granite. Nowhere in the district has the slightest trace of ore been found in the granite. The ore rarely contacts the granite, and then only sparingly or sporadically, its normal position being between the garnet ledge and the limestone, and irregularly impregnating both. The most persistent and strongest ore bodies, again, are associated with the non-contact garnet zones, which are, in part, far removed from the nearest border of the granite. In no

[1] Origin of Pegmatite, American Geologist, **19**, p. 170.

instance has it appeared possible to correlate the ore bodies with antecedent fissures, which might, conceivably, have served as channels of supply from underlying granite. The demonstrated faults of the district are clearly newer than the ores; and the latter sometimes exhibit beautiful slickensides where traversed by shear planes and displacements.

The main body of the limestone, apart from the garnet zones and ore deposits, is apparently as barren of ore as the granite; and accepting either of these formations as the source of the ore forces the conclusion that the processes of segregation and concentration have been singularly complete, although it is, of course, possible that refined analysis would prove the presence of zinc and copper where none are apparent to the eye. The plain indications are that during the metamorphism of impure and presumably metalliferous beds of the limestone to form the garnet zones, the metallic sulphides contained in these beds, and possibly in large volumes of the adjacent strata, were segregated by metasomatic process along the common boundary of the garnet zone and the limestone.

As previously noted, Washington Camp is undoubtedly an outlier, isolated by igneous intrusion and erosion, of the great series of Paleozoic limestones in which are found a very large proportion of the ore deposits of the Rocky Mountain region and the Pacific coast, as well as the widespread and rich zinc and lead deposits of the Mississippi Valley, the last mentioned district having been from the beginning of Paleozoic time remarkably free from every phase of vulcanism, and having suffered as little deformation as any part of the continent.

It appears difficult, in view of these considerations, to find any warrant for doubting that this great limestone series, or some part of it, is normally and originally metalliferous, or that, stimulated by intense and long-continued igneous and metamorphic agency (which was not required in the Mississippi Valley), the circulation of the normal ground water has proved equal to a more or less complete concentration of the metallic contents of the limestone.

Structural Details

It is proposed to give here some local observations, which, although not conveniently included in the foregoing discussion, are of interest in their bearing upon the general theory of the district.

West Contact. — Beginning at the north end, a shaft on the Kansas claim 150 feet from the limestone-quartzite contact and 100 feet deep to water level, with about 200 feet of drifting, shows mainly pyrite, with subordinate chalcopyrite, galena, and blende, and abundant quartz gangue. The main ore body is vein-like in form, but without walls, and clearly a replacement in the limestone, with many isolated bunches or pockets of ore 3 inches to 3 feet or more in diameter, and usually parallel to the main ore body and the bedding of the limestone. The garnet ledge is not developed here, but a feature of special mineralogical interest is found in the pseudomorphic cavities due to the oxidation of the pyrite.

Next south of this, on the New York claim, where the garnet ledge is also wanting, a shaft 205 feet deep has developed, at a distance from the quartzite contact, one large and one smaller irregular ore body, carrying above the water level good values in lead and silver.

Between the New York and Maine claims the quartzite is broken or sharply flexed, being offset to the west several hundred feet, on the northern slope of Washington Mountain; and the garnet ledge is developed on the blending contact of the quartzite and limestone. Mingled with and following the garnet is the ore-impregnated limestone. All along this western contact the reaction zones of wollastonite are a nearly constant accompaniment of the chert lenses and nodules in the limestone; but this feature gradually dies out as we recede from the granite.

On the Elia claim, crossing the upper western slope of Washington Mountain, the basal quartzite is well developed, with a breadth of 100 to 200 feet; and, as before, it separates the garnet ledge, some 50 feet wide, from the granite. The ore, which runs largely to black sphalerite, in part admirably crystallized, occurs chiefly in the inner part of the garnet zone, forming an irregular, weak, or fragmentary body, accompanied by some striking stellate groups of quartz crystals.

On the Contact claim, crossing the hill at the head of Bonanza Gulch, this section is repeated from the granite through the quartzite and the ore-bearing garnet zone to the limestone; but, although the garnet zone is strong, the ore is weak and does not form continuous bodies. These conditions recur also on the Montezuma claim, which marks the southwest corner of the district; but the basal quartzite is here distinctly ferruginous, and carries low values in gold.

On the Lead King claim, at the extreme southern end of the district, the granite is well exposed in two tunnels driven to cut the contact.

Although of a highly acid and, in the main, essentially normal character, it is in part, also, more or less pyritiferous, the pyrite occurring chiefly but not wholly in the seams. No other instance of mineralization of the granite has been observed.

East Contact. — Toward the southern end of this contact is the chief occurrence of porphyry, which appears to be somewhat later than the granite and of rather more acid character; but, so far as observed, does not differ from the granite in its relation to the limestone and the ore bodies. The eastern garnet zone follows the contact somewhat continuously across the San Antonio and Duquesne claims to the Bonanza claim, on which is located the Westinghouse shaft, 650 feet deep. The shaft starts in the porphyry; but all the lower part is in coarsely crystalline white limestone, and the bottom is said to be 65 feet from the porphyry, proving that the contact overhangs the limestone a little. Farther north along this contact the garnet zone and ore bodies are wanting, and we pass abruptly from the granite or porphyry to the gray to white marble, which is uninterrupted for a breadth of 1,000 feet.

North of Washington Post Office the contact is easily traced, and where it is crossed by the road for the last time it is well exposed in a cutting, showing normal granite against white crystalline limestone, with no signs of a garnet zone, although a prospect hole shows a thin line of ore, while a little farther north a line of prospect holes shows that the contact is there more heavily mineralized.

Central Ore Zones. — These zones practically begin with the Pride of the West claim, in the latitude of Washington Post Office. This property, which produced a large amount of oxidized lead-silver ores above the water level twenty-five years ago, embraces two ore horizons 10 to 20 feet thick, separated by 20 to 50 feet of limestone, and dipping west 33° beneath the eastern dike of granite, which forms the hanging wall of the western ore body, and is, in turn, overlain by a heavy bed of chert. The granite seems to conform with the bedding of the limestone, but the under surface of the granite or hanging wall of the ore is very plane, more or less coated with garnet, as a rule, and beautifully slickensided. This is evidently a fault plane which has apparently cut out the main part of the contact zone.

In their southward extension to the next ridge these ore bodies leave the granite dike and are thrown eastward, with the great bed of chert, 500, and possibly nearly 1,000, feet by a transverse flexure or fault. Beyond this displacement they are continued, still on the east

side of the chert, in the similar and parallel ore bodies of the Smuggler claim. Some 300 feet farther east is the parallel ore zone, 10 to 15 feet thick, of the Texas claim, which has not been identified on the Pride of the West ground. The Texas ore is chiefly blende, with walls of limestone, and the garnet zone is not prominently developed north of Double Standard Gulch; but we have now, in addition to the displaced continuation of the double Pride of the West ore zone on the Smuggler claim, and still holding the same relation to the great bed of chert, though now widely separated from the granite dike, the parallel ore zone of the Texas claim.

A series of prospect holes extending from the Smuggler workings shows very clearly that the dual ore body is here flexed backward, and, pinched and dragged out, trends directly toward the tunnel on the Double Standard claim. In other words, we have here a compensating displacement, the dual ore body being thrown from the south end of the Pride of the West claim eastward into the Smuggler claim, and then westward again into the Double Standard claim, where both members, with their normal characters, have been cut by the Double Standard tunnel. The fact that the granite dike is not thrown with the chert bed and ore zones indicates that the displacements in this case antedate the intrusion of the granite; but that there has been some movement, at least, along these breaks subsequently to the formation of the ore is made very clear by certain phenomena brought to light in the Double Standard workings. The tunnel cuts the ore zones just at the break where they are regaining the normal north-south strike, and a winze was sunk at this critical point on the eastern zone. That this winze is directly in the zone of crushing and disturbance accompanying the great fault is evident from the highly broken and cavernous condition of the ground. That the movement to which this broken and open structure is due was subsequent to the metamorphism of the limestone and the formation of the ore bodies is unquestionable, since both are involved in the crush breccia. But that this movement was also accompanied or followed by conditions favorable to ore deposition is proved by druses of pyrite, sphalerite, quartz, etc., and especially by the occurrence of a cavity several feet in diameter lined with a reniform layer or crust of native arsenic, 1 to several inches thick. This occurrence of native arsenic, which has been described by Dr. C. H. Warren,[1] undoubtedly finds its best explanation in thermal

[1] American Journal of Science, 1903, **16**, pp. 337–339.

waters rising along the fault; that is, in something analogous to fumarole action.

On the ridge which we have now reached, separating Double Standard and Bonanza Gulches, a section from east to west across the ore zones shows: (1) the displaced extension of the ore zone first recognized on the Texas claim; (2) a strong and typical garnet zone; (3) the double ore zone of the Pride of the West, Smuggler, and Double Standard claims; (4) the massive chert formation everywhere overlying the dual ore zone; (5) an unmeasured thickness of crystalline, gray limestone; (6) the Holland ore zone, not previously recognized, with its garnet zone. All of these various horizons are recognizable again, south of Bonanza Gulch, in the Annie, Mary Jane, and other claims; and still farther south, on the Empire and Belmont claims, the garnet zones, if not the ore zones, appearing to gain in strength as we approach the granite.

BOOK REVIEWS

Technology in Japan[1]

We have received two journals from two of the imperial universities of Japan, from which it is evident that a spirit of research prevails at those centres of learning, and that it is being developed along technical as well as scientific lines. This is shown by the contents of the first number of the *Memoirs of the College of Science and Engineering*, Kyoto University, which are as follows: "Synthesis of Indigo and Its Methyl Derivatives," by M. Kuhara and M. Chikashige; "Ueber die Veränderung der Elektrischen Leitungsfähigkeit eines Pulvers durch Induction," H. Muraoka and T. Tamaru; "On the Filings Coherer and Wireless Telegraphy," T. Mizuno; "Electric Resonance," T. Mizuno; "A Graphical Representation of Potential Drops and Distribution of Currents in a Network System," E. Aoyagi; "On the Solubility of Gold-silver Alloys in Potassium Cyanide Solutions," J. Yokobori; "Defects of Uncarburetted Water Gas as Fuel for Laboratory Use," M. Chikashige and H. Matsumoto; "On the Allanite Crystal from Hiei Mountain," T. Hiki; "Deflection and Vibration Diagrams of Kinokawa Railway Bridge Truss," S. Tanabe; "Note on the Body of Awata Pottery," H. Matsumoto; "Note on the Influence of Solvents upon the Formation of Chloracetyldiphenylamine," M. Kuhara and M. Chikashige.

The first number of the second volume of the *Journal of the College of Engineering*, Tokyo University, contains a single memoir of seventy-four pages and six plates, describing "Experiments on Vibration of the Japanese Torpedo Boat No. 18 and the Torpedo Boat Destroyers *Harusame* and *Hayatori*," by F. Omori, F. P. Purvis, C. Shiba, and S. Terano.

It is interesting to note that all of these papers are written in English, except one in German, and their contents are thus made

[1] Memoirs of the College of Science and Engineering, Kyoto Imperial University. Kyoto, 1903, I, No. 1, 91 pp., il., O.

Journal of the College of Engineering. Tokyo Imperial University. Tokyo, 1904. II. No. 1. 74 pp., 6 pl., O.

available to scientific men in all parts of the world. There is a striking difference between this and the current usage in Russia, where formerly scientific results were made available to men of other nations by being published in French or German. But now the Russians publish everything in their own language, and if it were not for a few foreigners who, being familiar with that difficult tongue, occasionally publish abstracts, generally in German, of Russian articles, the scientific activity of Russia would be entirely unknown to the outside world.

Food Preservatives[1]

A prominent feature in the active warfare waged so strongly in the last few years against the production and sale of adulterated foods has been the antagonism manifested toward certain food preservatives. One side of the question has been kept prominently before the public mind to the exclusion of the other.

Reports of court trials, publications of state and municipal laboratories, legislative bodies, through enactments, have dwelt upon the dangerous nature of these preservative chemicals and the public harm that would result from their use in food.

Scientific authority, however, has not been quite so sweeping in its condemnation, and the impression left in the mind of a candid and thoughtful reader of the experimental evidence would be a contradictory and inconclusive one concerning the danger to be actually expected from artificial preservatives as practically used.

In the present volume the subject is discussed from the standpoint of the manufacturer, and while the statements made and the evidence recorded are, as might perhaps be expected, chosen to defend a certain position, they cover a wide range of experience, and give evidence of diligent research into the literature of the question.

The book is devoted mainly to the discussion of a typical preservative — salicylic acid; but descriptions of other important preservative chemicals are given, together with an enumeration of the classes of foods in which they are commonly used and methods for their detection.

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[1] Food Preservatives: their Advantages and Proper Use. The Practice *versus* the Theoretical Side of the Pure Food Problem. By R. G. Eccles, M.D., Phar.D. New York Van Nostrand. 1905. v + 202 pp.

In this connection exception must be taken to the procedure for the detection of benzoic acid described on page 41. In the reviewer's experience the formation of aniline blue by heating the extracted residue with rosaniline hydrochloride and aniline is not a characteristic test for benzoic acid. The color obtained is not a function of the benzoic acid, and, furthermore, the test is given equally well by salicylic acid, stearic acid, and several other agents which act as catalyzers of the reaction.

The author pays his respects to many of the government officials and especially to Dr. Wiley and his "poison squad," the results from the latter being discounted because of the effects of fear which were not eliminated, and because of the method of procedure adopted.

A pertinent paragraph calls attention to the fact that food commissioners for some reason do not interfere with syrup and candy men for sulphites in their glucose and other sweets as they do with catsup and fruit-juice bottlers. It is intimated jocularly that this may be because candy is eaten largely by children, and in the opinion of the food commissioners they do not count.

Much of the discrimination against food preservatives is charged to the account of the widespread idea that, the process of digestion being a process of "fermentation," any substance which will prevent fermentation in food will be all the more harmful in digestion. This idea the author considers a relic of former times when the distinction between "fermentations" caused by bacterial action and those brought about by enzymes was not recognized.

The use of preservatives is discussed also in connection with the temperance question, alcohol in fortified wines being held to be a preservative more harmful than either salicylic or benzoic acid.

The book as a whole is one which is worth reading by any fair-minded person who is interested in food preservatives, and one from which food commissioners and legislators might get a broader view, even though they felt compelled to disagree with certain conclusions drawn by the author.

A. G. Woodman.

Geology of Western Australia[1]

Through the kindness of Mr. A. Gibb Maitland, government geologist, we have received a series of the Bulletin of the Geological Survey

[1] Western Australia, Geological Survey. Bulletin Nos. 6 to 15. Perth, 1902–1904. Plates: maps. O.

of Western Australia. As might be expected, these publications deal largely with the geology and mineralogy of the gold fields. The contents of the Bulletins are as follows:—

Bulletin No. 6. "Notes from the Departmental Laboratory," by E. S. Simpson. 1902. Contains analyses of a number of minerals and rocks.

No. 7. "Notes on the Auriferous Reefs of Cue and Day Dawn," by W. D. Campbell. 1903. Text and map.

No. 8. "Lennonville, Mount Magnet, Boogardie, Murchison Gold Field," by C. G. Gibson. 1903. Text and geological sketch map.

No. 9. "Geological Features and Mineral Resources of Northampton," by A. G. Maitland. 1903. Text and geological map, with sections showing results of boring for copper and lead.

No. 11. "Notes on the Country between Edjudina and Yundamindera, North Coolgardie Gold Field," by A. G. Maitland. 1903. Text with two maps.

No. 12. "Geological Features and Mineral Resources of Mulline, Ularring, Mulwarrie, and Davyhurst, North Coolgardie Gold Field," by C. G. Gibson. 1904. Text with two maps.

No. 13. "Geology and Auriferous Deposits of Leonora, Mount Margaret Gold Field," by C. F. V. Jackson. 1904. Text with map and sheet of sections.

No. 15. "Preliminary Report on the Geological Features and Mineral Resources of the Pilbara Gold Field," by A. G. Maitland. 1904. One hundred and eighteen pages, twenty-five illustrations, eight maps.

Bridge Construction[1]

This is a type of book of which there should be more numerous examples. It is a collection of facts and figures, largely from the pages of the *Engineering Record*, regarding a large number of arch structures in all parts of the world, and is very fully illustrated. The writer is well known through his connection with the *Engineering Record* and as a lecturer on engineering subjects. The object of the book, as stated by him, is to present the development of advanced practice, both as

[1] Types and Details of Bridge Construction. Part I, Arch Spans. By Frank W. Skinner. New York: McGraw, 1904. 289 pp.

regards types of structure and details, to illustrate the classes of structures adapted to different conditions, to show some of the characteristic differences between American and foreign designs, and to put on record in easily accessible form the principal data regarding important and well-known examples of each of these types of structures. The work is confined to facts regarding structures which have actually been built. It has very little mathematical or analytical discussion, and contains no description of projects made merely on paper but not executed. Both good and bad methods of construction are shown, together with some that are curiosities, and some which have been superseded on account of improved methods of design or manufacture.

The work is divided into four parts, treating respectively of wood and iron arches, spandrel braced arches, arch trusses, and plate girder arches; and under these heads most of the important structures in the world are referred to in considerable detail.

Altogether the work is a valuable contribution to engineering literature, and we hope that it may be followed by others of the same character treating of other types of structures. Information of this kind is generally scattered through the pages of engineering periodicals, where it is apt to be buried and forgotten, as well as inaccessible to many. To collect and arrange these details in a well-illustrated book is a labor worthy of much commendation.

G. F. S.

Cement and Concrete[1]

The past year has produced a number of important and noteworthy works on the subject of cement and concrete. The rapid development of concrete construction, and especially its applicability, when reënforced by steel, to structures of the most varied types, makes this material appear one which offers great possibilities for the future. During the past few years numerous tests have been made upon its various properties, and studies carried on regarding its constitution; and our knowledge regarding these matters has been very greatly increased. One of the very best of the works which has appeared regarding this subject is the one by Mr. Sabin, who, during his connection with the

[1] Cement and Concrete. By Louis Carlton Sabin. New York: McGraw, 1905. 507 pp.

Engineering Department of the United States Army, has made many researches and tests regarding cement and concrete, and who is well known as an expert on the subject and as a member of the committee of the American Society of Civil Engineers on tests of cement. In this work he has gathered together and classified about all the information which any one could desire with reference to the subject. Part I treats of the classification and manufacture of cement; Part II, of the properties of cement and methods of testing; Part III, of the proportions and properties of mortar and concrete; and Part IV, of the use of mortar and concrete.

The work is admirably arranged, and is accompanied by a very large number of tables giving comparative results of tests and experience. Of these tables there are no fewer than 161. There are also valuable tables of costs, which will be found very useful to the contracting or constructing engineer. The results of the most recent investigations, both in America and abroad, regarding the properties of concrete and the mechanical and chemical theories regarding its composition, are fully discussed and the results made very clear. The testing of cement, and the interpretation of the results, the character of the sand and stone, the effect of foreign substances, of exposure to frost, and many other matters, are considered in detail, but with admirable conciseness and clearness. The methods of placing concrete, the types of reënforced concrete structures, the strength of reënforced concrete beams, and various miscellaneous uses of this material are also treated, always concisely and logically. It seems invidious to criticise in any way so thoroughly excellent a work, but we think its value would be increased if the illustrations were more numerous.

Altogether the work may be recommended without qualification to the student and to the engineer. It is accompanied by a useful index.

G. F. S.

Steel Sections[1]

This is a valuable little book of reference for structural engineers, giving tables of data more extended in certain directions than those given in the usual handbooks of information. Twenty-nine tables are given, with values of moments of inertia and radii of gyration for

[1] Properties of Steel Sections. By John C. Sample. New York: McGraw. 121 pp.

various sections, such as two angles in various positions, four angles with varying distances, plates and combinations of plates and angles, Z-bar columns, channel columns, combinations of channels and I-beams, channels and plates, etc. Illustrations are given of types of columns for large buildings and of top-chords for bridges, taken from actual structures; also tables and curves for various column formulæ, and the safe loads for columns of various shapes, such as two angles, four angles and a plate, channels at varying distances apart, together with other miscellaneous information.

The book will enable a designer to sketch out rapidly a preliminary design, and may be recommended to those who have much of this work to do.

G. F. S.

Professional Papers of Dr. Waddell[1]

This volume of nearly one thousand pages is a collection of the various papers and addresses by Dr. Waddell during the past thirty years, with comments by the editor, and with discussions in cases where these papers were submitted to professional societies. About one-third of the book consists of these discussions and comments.

Of these papers a certain number have reference to education, some of these being addresses before engineering classes at various institutions. Two of the earliest ones are upon railroad matters, and the remainder have reference to bridge construction.

The educational papers consist of an address before a Japanese society of engineers, a paper upon civil engineering education published in the *Engineering News* in 1887, some further notes upon civil engineering education with special reference to Japan, a letter relating to civil engineering education, a plea for instruction of engineering students in the history of engineering, and addresses before engineering students of the Rose Polytechnic Institute, Missouri State University, and the University of Nebraska.

In these papers many suggestive thoughts and many sound suggestions will be found, intermingled with some which will seem to most teachers impracticable.

[1] The Principal Professional Papers of Dr. J. A. L. Waddell, C.E. Edited by John Lyle Harrington. New York: Virgil H. Hewes, 1905.

Dr. Waddell's suggested courses in engineering would seem to be laid out in such a way as to cover every possible subject which would be brought to the attention of the engineer during his entire lifetime. Such a course would be impossible on account of lack of time, and would not in any case be advisable. The principal object of an engineering course should be to give the student the power to think and to act, so that if perchance in his practice he encounters a subject he has not studied he will be able to take it up and master it to an extent sufficient for his purposes. Dr. Waddell's own career, as exemplified in the interesting biographical notes prefixed to the volume, is a good example of this very point. His own engineering training did not begin to cover the subjects which he suggests, yet he has not lacked the power to master the problems which have been presented to him, and his success has been all that could be desired. Many of the things which the student learns in school are entirely forgotten, but the power which is acquired remains. Dr. Waddell attaches too much importance to information and too little to training. The course of study which he proposes, moreover, is ill-balanced and too diffuse, and the subjects do not come in proper order. Some of his suggestions, too, will make the experienced teacher smile; as, for instance, that he should glance over every new book connected with his work, and if it prove to be good should read it carefully and include the gist of it in his lectures, or compel his students to read it; also his suggestion that a technical school should launch out even ahead of technical literature, and obtain directly from practicing engineers the very latest information for its students; also that the vacation period should be reduced to one month; and sundry remarks with reference to our present American schools which show a lack of information regarding many of them. In many respects, however, his suggestions are valuable and well worth studying, and many of his ideas, if put into effect, would prove very salutary.

At the present time some of his remarks with reference to the Japanese are particularly interesting, as, for instance: "By much practice, . . . and systematizing of methods, one can so train the mind as to grasp readily mathematical reasoning, see at a glance mathematical deductions, and perform readily very difficult mental feats. In this respect the Japanese far excel Europeans and Americans. The amount of work that a Japanese science student gets through in a day would appall most of the men in an American university. Moreover, they do it just as thoroughly as their American brethren, and without spending

upon it any more time." This is the testimony of others who, like Professor Waddell, have taught in Japan.

The two short papers on railroad drainage and notes on railroading contain many practical points of interest and value. The principal portion of the book, however, is taken up by papers regarding structural subjects, including specifications for highway bridges, a description of the Halsted Street lift-bridge and of the Kansas City flow line bridge repairs, a paper on specifications in general, another on foundations of important buildings in the city of Mexico, and Professor Waddell's two principal papers before the American Society of Civil Engineers, on "Disputed Points in Railroad Bridge Design," and on "Elevated Railroads," with the accompanying discussions. These papers contain a large amount of valuable information, and it is interesting to compare the opinions of eminent engineers with reference to the points discussed.

Altogether the book is highly creditable to its editor as well as to the author, and it should be remarked that the editor's own comments, following many of the papers, are not the least interesting portion of the volume. The typography and general character of the book are excellent; and if the range of subjects treated is somewhat wide, it is, on the other hand, well worth while to have brought together and preserved in one volume the various papers here collected.

G. F. S.